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ABSTRACT

This 4-year longitudinal study of logical reasoning found complex interrelationships among different cognitive processes of children ages 6 to 15. Piaget's stage theory is discussed in the introduction, with a focus on the concrete operational stage in middle childhood. In the study, a representative array of logical concept tasks and short-term memory measures was administered to children at the kindergarten, third, and sixth grade levels. Of the initial sample of 134 subjects, 88 participated in all four years. The target domains included relations (e.g., seriation), classification (e.g., class inclusion), natural number (e.g., number conservation) and conservation (e.g., equivalence of weight), and the groupement structures into which they enter. The relative difficulty of the tasks, age-task and other interactions, and the connections among the abilities involved are described statistically. It is suggested that the data fit the sigmoid sequence (a series of ascending curves) of stage transitions proposed by Feldman and Toulmin, in which some skills develop in a lock-step fashion and others relatively independently of one another, better than the classical model of stepwise transitions. It is concluded that the primary research question concerns the modifications necessary in the Piagetian concrete operations stage designation to permit it to play a continued role as a potential explanatory construct in more complete accord with developmental reality. Data are presented in 39 tables (comprising nearly half of the report), and there are 14 figures representing grade or age by performance means for the different tasks. (Author/BH)

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LOGICAL REASONING IN MIDDLE CHILDHOOD

A STUDY OF THE PIAGETIAN CONCRETE OPERATIONS STAGE

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General Introduction

Any person setting out to conduct normative research based upon Piagetian theory does so with genuine feelings of humility and trepidation. Humility appears appropriate in the face of the enormous volume of original ideas and associated research that have come from Geneva. The sheer amount of Piaget's published works alone (over 1500 citations as of 1974) probably ranks him with such individuals as Wundt and Freud and presents major bibliographic and archival difficulties (see the Catalog of the Jean Piaget Archives, and the January 1970 issue of the *American Psychologist*, 1970, 25[1], 65-79, for a comprehensive listing of his published works up to that time). One then must add the work of Piaget's various collaborators (e.g., see the numerous volumes of the *Études D'Épistémologie Génétique* series) and large number of secondary and derived studies currently available in the literature (Flavell, 1970). Feelings of trepidation arise when the complexities and operational vagueness (from the typical Anglo-American logical positivist perspective) of the Piagetian system become apparent. Piaget's theory quite naturally is a product of the European tradition of philosophical and psychological inquiry with emphases upon logical analysis and clinical assessment of children in quasinatural settings. As such it represents an orientation somewhat different from the Western experimental and psychometric traditions.

Nonetheless, Piagetian theory and the inspired research is itself an organic entity that must be viewed as changing and modifiable over histori-

cal time (see Piaget, 1970, p. 703, fn.). Thus, additional empirical research that seeks to evaluate the developmental congruence between the stage independent and stage dependent assumptions of Piagetian theory and the changing behavioral patterns of growing children is appropriate and is essential to a better understanding of genetic epistemology. It is in this spirit that the present investigation was undertaken. We sought to evaluate the performances of a group of children aged 6 to 15 years on a representative array of logical reasoning tasks in a modified cross-sequential sampling and assessment design (Wolhwill, 1973). As the age-range implies the major focus was the concrete operations period of middle childhood.

Stage Independent Aspects

It has been suggested that these general aspects of the Piagetian "world view" (Reese & Overton, 1970) may be distinguished by two questions: the synchronic development and the diachronic development (Flavell, 1963, pp. 262-264; Feldman & Toulmin, 1976). The synchronic aspects of the Piagetian system concern the complex of events native to a particular time period or stage and largely ignore the historical antecedents (genetic precursors in Piaget's case) and transition factors or processes that govern cognitive growth across the life-span. In contrast, diachronic aspects refer to the stage independent assumptions of the general theory and emphasize the change processes that govern the transitions across the major and minor developmental subperiods. In this latter category, Piaget identifies four major determinants of cognitive growth. These are (1) organic growth factors that are biologically constrained but not reducible to heredity or genetic preprogramming alone, (2) functional exercise and experience with the physical world, (3)

social transmission, and (4) the equilibration process (Piaget & Inhelder, 1969, pp. 154-159). Maturation, as Piaget makes clear

> is undoubtedly never independent of a certain functional exercise where experience plays a role (and further) . . . the maturation of the nervous system simply opens up a series of possibilities . . . without giving rise to an immediate actualization of these possibilities so long as the conditions of material experience or social interaction do not bring about this actualization (and finally), this actualization presupposes certain conditions of physical experience such as the manipulation of objects, etc., which is also essential for logic, and certain social conditions such as the regulated exchange of information, mutual control, etc. [Piaget, 1967, pp. 119-120].

Of course the most important and unique determining process for Piaget (indeed it may be seen as assuming distinctly superordinate status) is equilibration. As we have stated previously,

> Equilibration refers to the self-regulatory process which governs the functional relations within the individual's action systems and provides the conceptual setting for the organism-environment interactions. Attempts to designate operational definitions for the equilibration processes and related equilibrium states have typically evidenced circular reasoning and have been restricted to differential response probabilities in rather specific task formats, such as conservation measurement (Flavell, 1963, pp. 244-249; Furth, 1969, pp. 261). In certain instances the term is used to describe the <u>internal</u> organizing factors which underlie sensorimotor action schemes and higher level representational schemas and their coordination (Langer, 1970). In others the equilibration "mechanics" are said to mediate the macro-level exchanges between the active organism and its surrounding milieu. In the latter sense, a state of equilibrium is perhaps most readily viewed as subsuming the assimilation and accommodation processes. A preponderance of one process over the other denotes the unstable conditions typical of the initial preparatory phases of a particular stage or developmental period. A complementary, balanced relationship between the assimilatory and accommodatory aspects is the hallmark of established stage-specific functioning and serves as the defining criterion for adaptation [Klausmeier & Hooper, 1974, p. 8].

The complementary "constructs" of organization and adaptation are operationally present throughout the life-span and thus provide the essential continuity in Piaget's system (the label functional invariants may

be applied here). The former term (organization) leads one to a consideration of structure (and eventually stage descriptions) while the latter refers to functional aspects particularly the assimilation accommodation dyad. Assimilation (which may be considered as temporally preceding accommodation, although it can only be abstractly viewed as a separate entity) is the incorporative aspect of an operative action or scheme, that is, "A taking in of environmental data, not in a causal mechanistic sense, but as a function of an internal structure that by its own nature seeks activity (Furth, 1969, p. 260)." Thus, incoming stimulation (aliment) is modified vis-à-vis the individual's current structural status. Correlatively, accommodation is the outgoing aspect of an operative process and signifies the modifications that occur in the individual's cognitive organization as a natural consequent of environmental intrusions.

From the Piagetian perspective, all cognitive acquisitions including object, self, and self-object relationship concepts are the outcome of an active constructive process. Thus, Piaget may be termed a "constructive rationalist" (Beilin, 1971, p. 92). His constructivism is neither idealist nor realist in basic orientation since knowledge depends <u>both</u> upon the available mental structures and the products of physical and social experience. Such conceptual categories (taken in the Kantian sense of this term) as space, time, relationships, classes, and quantitative invariants are not present at the onset but develop over time in a series of interesting evolutions. These interesting evolutions are marked by definite systematic structural changes that involve the stage dependent aspects of Piagetian theory.

Stage Dependent Aspects

Stages and developmental periods are perhaps the best known and most controversial component of the Piagetian system. Recent conceptual analyses of the Genevan version of developmental stages include essays by Beilin (1971b), Brainerd (1978b), Feldman & Toulmin (1976), Flavell (1971), Hooper (1973), Pinard & Laurendeau (1969), and Wohlwill (1973, chapter IX, pp. 190-239). These accounts have highlighted the theoretical emphases and associated empirical issues associated with stages as descriptive, metaphorical, and (potentially) explanatory constructs. Piaget identifies four major criteria for cognitive stages, hierarchization, consolidation, integration and structuring, and equilibration (Piaget, 1956, 1960, 1970a).

> Hierarchization refers to the well-known postulate of stage invariance or transitivity of progression throughout the developmental sequence. Later stages or levels can never precede the earlier acquisitions; i.e., in the sequence of stages, A-B-C-D, all individuals demonstrate C capabilities after Stage B and prior to Stage D. Integration (per se) is a closely related concept which specifies that subsequent stages or levels 'transform' earlier stage behavior into new structural entities. Prior stages are not simply replaced (in an additive or substitutive fashion), but rather become subordinated and subsumed within the higher level functioning. This implies that later stage-related behavioral manifestations cannot be exhaustively (i.e., the complete antecedent-consequent version of efficient causation) predicted or causally linked from information specific to earlier modes of responding although the converse relationship may hold [Hooper, 1973, pp. 303-304].

This last property or attribute of stage progressions concerns the "emergence" assumptions of Piaget's theory that is shared by all organismic viewpoints (Nagel, 1957; Reese & Overton, 1970).

Consolidation refers to the fact that each stage or period has a preparatory and stabilization phase associated with it (indeed, each intermediate stage in the Piagetian system is viewed as the culmination of all those that have come before and the starting point for all those to follow).

Early stage-specific behaviors are transitory and "reminiscent" of the earlier modes of functioning. Typically old means (structures) are applied to the new ends (functional demands), Werner (1957). Gradually the child's new response repertory becomes generalized and more stable, which in turn sets the stage for the next developmental transition via the equilibration dynamic.

The structural and integration assumpsion is unquestionably the most salient aspect of a meaningful stage designation for Piaget. As one of us has commented previously:

> All the organizational simplicity and potential explanatory parsimony follows from the *structures d'ensemble* postulate. For Piagetian theory the behavioral outcomes of this assumption have been described under various labels, e.g., interrelationships between responses to different tasks involving the same operations (Wohlwill, 1963), operational convergence (Beilin, 1965), functional correspondence (Hooper, 1973), significant interitem correlations (Braine, 1959; Shantz, 1967), complete functional interdependence and organic connections (Pinard & Laurendeau, 1969), concurrences (Flavell, 1970, 1971), and interpatterning among sets of developing responses (Wohlwill, 1973). All of these designations highlight the intraindividual and interindividual uniformity across response domains which is to be expected of persons "located" in a given stage of development. Moreover, contrary to Brainerd's (1978b) conclusions, the integration assumption implies more than a merely additive notion of each successive stage including the earlier stage's dominant response prototypes, as subcases within the individual's behavioral repertory. Rather, the later (chronologically defined) and more complex (logically defined) stages or levels of development effectively transform and reorganize the earlier levels of responding into new functional entities. Thus lower order responses become subordinated in terms of their organizational properties as higher stages are achieved and assume different functional roles in contrast to those of the earlier periods. This is the essence of the qualitative changes associated with stage transitions in organismic theory (Pinard & Laurendeau, 1969; Werner, 1957; Werner & Kaplan, 1963) and are exemplified in the changing relationships among sensory-motor, perceptual, and logico-symbolic functioning across the human life-span. Increased differentiation (the additivity and specificity assumption) is always accompanied by a concomitant increase in hierarchic integration (Werner, 1957). What this means in behavioral terms, of course, is that lower level response modes, e.g., the perceptual, assume qualitatively different functional salience

> after higher level potentials, e.g., the symbolic, are attained. This in no manner denies the possibility that earlier dominant response categories may continue to evidence progressive development during later stages and may indeed become temporarily characteristic during periods of stress or functional disruption (Flavell, 1971, 1977; Langer, 1970).
>
> This necessarily leads to major problems in accurately "diagnosing" an individual as belonging in any developmental stage (except of course the initial stage in any developmental progression). In particular it makes somewhat problematic the developmental synchrony or "abruptness" assumptions usually associated with Piagetian stage transitions. However, some recent writers have questioned the logical necessity of synchronous stage related behavioral acquisitions within the Piagetian system (Feldman & Toulmin, 1976; Flavell, 1970, 1971, 1977) and have proposed alternative models of development which retain the stage construct albeit in forms rather more complex and diversified than the conventional Genevan version (e.g., Wohlwill, 1973, pages 190-239) [Hooper, 1979, pp. 3-4].

These theoretical considerations pertain to all the general periods of cognitive growth, the sensori-motor (infancy), preoperational (early childhood), concrete operations (middle childhood), and formal operations (adolescence and adulthood), but they are singularly germane to the concrete operations case. This period has received the attention of the majority of Neo-Piagetian researchers.

The Structure of Concrete Operations Period Thought

There is a considerable body of original and derived research that is concerned with concrete operations period functioning. The original Genevan sources include Inhelder & Piaget (1958, 1964), Piaget (1942, 1970a, 1970b, 1971, 1972), Piaget & Inhelder (1956, 1962), Piaget, Inhelder, & Szeminska (1960), and Piaget & Szeminska (1952). The logical concept content domains include classes, relations, number, conservation of quantitative invariants, logical inference, and probability, in addition to the related infralogical concepts dealing with space, geometry, time, velocity and movement, and distance. Representative reviews of this research and the secondary repli-

cation studies are found in Brainerd (1978a), Flavell (1970, 1977), and Sigel & Hooper (1968).

The major characteristics of concrete operational thinking may be described in psychological qualities or in formal properties. This follows from the fundamental Piagetian assumption that a formal logical model is isomorphic to psychological functioning. Thus, such defining properties of logico-mathematical structures (Piaget, 1972) as composition, associativity, general and special identities, and reversibility find psychological counterparts in behaviors that exemplify an understanding of transformations rather than static configurations, decentration rather than centration, inferred reality rather than perceived appearances, and reversible operations rather than irreversibility as evidenced in the negation of classes and reciprocity of relations (Flavell, 1963, 1977). As we have stated earlier:

> In the strict sense, operativity becomes possible only during the middle childhood years. It is during this time that the child's cognitive activities become organized into coherent and integrated systems. The term "operation" is used to refer to these systems both as something the child has at his disposal and as something the child does (Furth, 1969). Concrete operations are internalized representations of coordinated actions which are themselves organized into larger coordinated systems called groupings or *groupements*. Viewed as something the child does, operations include the logicomathematical activities of adding, subtracting, dividing, setting terms in correspondences (as in the cases of classes and relations), and the infralogical activities with a specific spatiotemporal context which deal with quantity, measurement, space, and time concepts (Flavell, 1963, p. 166). Viewed as something the child has, operations must be considered as parts of a higher order structural organization [Klausmeier & Hooper, 1974, p. 9].

The term Piaget employs to describe the superordinate structures of the concrete operations period is *groupement*. These structures are proposed as interrelating and subsuming all logical reasoning during the middle childhood period. While nine separate *groupements* have been described by Piaget, the eight primary cases include four dealing with logical classes and four

counterpart cases concerned with logical relations. Brainerd (1972) has succinctly described the major dimensions of the *groupement* structures as follows:

> Piaget contends that a given structure S is engendered by either a cognitive operation and its inverse--if S is one of the four "class" *groupements*--or by a cognitive operation and its reciprocal--if S is one of the four "relational" *groupements*. In theory, the notion of "operation" can here be taken to mean almost any internalizable property of overt action. In practice, however, the notion may be restricted to the set-theoretic operations of union and intersection and the arithmetic operations of addition and multiplication. Thus each class *groupement* owes its existence to the fact that the cognizer is capable of simultaneously uniting and subtracting classes, while each relational *groupement* owes its existence to the fact that the cognizer is instantaneously aware of the reciprocal implications of the equivalence and difference relations produced by arithmetic addition and multiplication. To illustrate, the capacity simultaneously to add two subordinate classes to yield a superordinate class and to subtract one subordinate class from the superordinate class to yield the remaining subordinate class engenders a certain class *groupement* structure. Also to illustrate, the knowledge that A < B and B < C simultaneously implies both A < C and C > A engenders a certain relational structure. Although one may quibble with these claims about the origins of *groupement* structures on theoretical grounds, there is no denying their obvious empirical implication: If one wishes to conduct research on these structures, then one most certainly will have to focus on the unions and intersections of hierarchical classes and their inverses--on the one hand--and on the addition-multiplication of equivalence-difference relations and their reciprocals--on the other [Brainerd, 1972, p. 5].

In view of the fact that children's logical *groupement* related performances are theoretically predicted to emerge and demonstrate final mastery in parallel fashion, developmental synchrony is anticipated for the classificatory and relational concept domains. This prediction follows (Q.E.D.) from the orthodox Piagetian conception of stage structure and integration (described above) and underlies the key assumption of stage as a

structure d'ensemble. Relative consistent performances (low intraindividual variability) should be found for concept tasks (equated for general item difficulty and content distinctions) operationally designed to assess behaviors derived from common structural components. Thus equivalent tasks assessing, for example, class, relations, and natural number concepts should evidence similar relative item difficulties (cross-sectional data), congruent developmental acquisition sequences (longitudinal data), and highly predictive time-lag correlational patterns (factor analyses and panel-type relationship analyses with multiple assessment points).

A final issue concerns the possible role of such "performance" factors (as theoretically distinguished from structural or competence determinants) as stimulus salience, instructional set, response and attentional demands, and short-term memory requirements on logical concept acquisition. One of these potential influence variables, short-term memory span, was selected for study. As has been summarized previously:

> It was hypothesized that, in view of the surface task demands, individual differences in auditory memory span would predict a significant proportion of the variance of the class inclusion task, while visual memory would be more strongly related to combinatorial reasoning. If this were the case, it was argued that these performance aspects of the tasks should be taken into account in drawing inferences to underlying competence. In particular, relationships due to shared operational structures could be more accurately reflected by examining partial correlations, with the influence of individual differences in memory and the differing memory demands of the tasks statistically controlled.
>
> If it proved to be the case that shared variance among logical operations tasks is due, to a measurable extent, to shared perceptual demands of these tasks, one information-processing approach would lead the investigator to discount that portion of the relationship as "performance variance," and to estimate the degree of structural similarity of logical operations behaviors only from that portion of the relationship not so "explained." However, this approach depends on the view that memory is a passive capacity, the development of which causes the emergence

> of logical structures (McLaughlin, 1963). More recent, dynamic views of memory development suggest that emerging logical structures may themselves contribute to the development of memoric skills (e.g., Pascual-Leone, 1970; Norman & Rumelhart, 1975). Under this approach, it would clearly not be appropriate to partial out memory as a common cause of a spurious component of the relationships under study, since memory growth, to some extent, would be a result of this development [Swinton, Sipple, Hooper, & Hougum, 1977, pp. 2-3].

We now may examine the general results patterns for the Piagetian longitudinal study.

Summary of Piagetian Study Results

Preliminary Considerations

It will be recalled that the primary focus of the Piagetian investigation was the concrete operations period of middle childhood. Accordingly, a representative array of logical concept tasks and short-term memory measures were administered to children at the kindergarten, third, and sixth grade levels (see Table 1). The target concept domains included relations (seriation, and transitive inference of length and weight), classification ("some" and "all" understanding, dichotomous sorting, class inclusion, and combinatorial reasoning), natural number (number conservation, cardinality, arithmetic addition), and conservation (identity and equivalence conservation of length and weight). The younger kindergarten and third grade children received all the tasks each year including the 64 item *groupement* battery and the three memory measures. The sixth grade children received only the *groupement* battery, class inclusion, combinatorial reasoning, and the short-term memory tests.

No attempt was made to specify and assign children to conventional Piagetian stage categories (see, however, previous reports by Gonchar, 1975, which used a comprehensive stage designation strategy for the number concept

domain; and Dihoff, 1975; and Hooper, Toniolo, & Sipple, 1978 which employed pass/fail criteria). We elected to treat the data in a more conventional manner (by American standards) and have employed parametric variance analyses, trend comparisons, etc. While it has been argued (Overton & Reese, 1973, p. 84) that models such as Piaget's that assume "organized complexity" rather than linear causality, are not appropriately evaluated with statistical inference approaches that assume additivity and linear summation of interaction effects; it may be countered that the conventional ANOVA and related parametric correlational approaches are indeed suitable initial strategies for the present normative analyses designed to assess the original Genevan contentions (Hooper, 1976). The summary reported in this chapter is in no way intended to be a comprehensive account (the complete analyses and discussion will be presented in a later monograph (i.e., Hooper, Sipple, & Swinton, in preparation). Interim reports that have been previously published include a preliminary planning paper (Hooper & Klausmeier, 1973), a report of a pilot investigation using similar tasks (Hooper, Sipple, Goldman, & Swinton, 1979), multidimensional scaling analyses (Dihoff, 1975, 1976b), effects of language factors on classification performances (Dihoff, 1976a), investigations of identity and equivalence conservation and related transitive inference (Brainerd & Hooper, 1975, 1978; Hooper and Toniolo, 1976; Hooper, Toniolo, & Sipple, 1978; Toniolo & Hooper, 1975), natural number concepts (Gonchar, 1975), theoretical papers discussing life-span analyses of Piagetian tasks (Hooper, 1976) and the present test batteries (Hooper, Brainerd, & Sipple, 1975), a report of a related training study with kindergarten and first grade children (Hooper, Wanska, Peterson, & DeFrain, 1979), an initial analysis of memory variables and logical reasoning (Swinton, Sipple, Hooper, & Hougum, 1977), and a summary of the first two years of

data collection for the present longitudinal sample (Hooper, Swinton, & Sipple, 1976).

Continued participation (selective survival) effects. Selected participation effects have been cited as a potential confound in longitudinal analyses (e.g., Baltes, 1968, Wohlwill, 1973) and have been found to bias the resulting normative generalizations significantly (e.g., Labouvie, Bartsch, Nesselroade, & Baltes, 1974; Riegel & Riegel, 1972; Riegel, Riegel, & Meyer, 1967). In the present Piagetian investigation, the mean percentage of "dropout" subjects per year was 8.5%, indicating moderate sample attrition from the longitudinal group across the three year duration. A total of 46 subjects did not participate in all four years' assessments: nineteen subjects from the initial kindergarten sample, 13 subjects from the third grade, and 14 from the sixth grade. Comparisons of these groups' first year performances with those of the four year longitudinal group indicated nonparticipant superiority of sixth grade subjects only on *groupement* VIII (means of 7.71 versus 6.83, $t = 5.27$, $df = 58$, $p < .03$). For the younger subject subsamples, two comparisons involving the same task proved to be significant. Continuing participants' some-all understanding task scores were higher than those of the "dropout" group for the kindergarten group (means of 3.63 versus 3.21, $t = 4.14$, $df = 58$, $p < .05$) and for the combined kindergarten and third grade sample (means of 3.74 versus 3.47, $t = 4.12$, $df = 118$, $p < .05$). Comparisons approaching significance were as follows: sixth grade means of 7.50 ("dropout" sample) versus 6.74 (longitudinal sample) on *groupement* VII, $t = 3.74$, $df = 58$, $p < .06$; third grade means of 19.77 ("dropout" sample) versus 16.96 (longitudinal sample) on the combined class *groupements*, $t = 3.68$, $df = 58$,

$p < .06$; kindergarten means of 3.16 ("dropout" sample) versus 1.90 (longitudinal sample) on the equivalence conservation of weight task, $t = 3.90$, $df = 58$, $p < .06$; kindergarten, third, and sixth grade combined means of 6.70 ("dropout" sample) versus 6.05 (longitudinal sample) on *groupement* VII, $t = 3.63$, $df = 178$, $p < .06$. It is clear from these results that few distinct performance biases are evident in the longitudinal sample and that the remaining sample may be considered representative of the original age-level cohorts.

Repeated measurement effects. Specific provision was made to evaluate the possible effect of repeated testing on the primary longitudinal sample children by assessing cohort-matched groups of subjects in the second and third year of the investigation (see Table 1). A series of analyses of variance were conducted to evaluate these potential biases.

Analyses of variance (sex, grade level, and longitudinal group versus testing control group) were employed (the means and standard deviations of the longitudinal and testing control group samples are reported in Hooper, Swinton, & Sipple, 1976, pp. 35-40). For the subset of measures that were administered to all subjects the evaluations indicated significant age-grade level main effects for 14 of 15 indices (see analysis summaries presented in Tables 2 and 3). Assessment group differences (repeated measurement effects) approached significance for the class inclusion task ($F = 3.59$, $df = 1, 216$, $.10 > p < .05$) and for the combined class *groupements* (I-IV) score ($F = 3.89$, $df = 1, 216$, $p < .05$). In both cases the core longitudinal group scores were consistently higher at all age-

grade levels. Sex differences and higher order interactions were generally nonsignificant for all the variables.

In the case of the first and fourth grade subjects who received the full task battery no cases of significant testing main effects were observed (see summaries presented in Tables 4 to 6). However, two instances of significant treatment group/grade level interactions resulted, i.e., conservation of length (identity task format) $F = 6.48$, $df = 1, 142$, $p < .05$, and conservation of length (equivalence task format) $F = 5.63$, $df = 1,142$, $p < .05$. Inspection of the means revealed the following: longitudinal group superiority (means of 4.46 versus 3.63; $t = 2.88$, $df = 70$, $p < .01$) at the first grade level and control group superiority (means of 5.83 versus 5.30; $F = 2.12$, $df = 76$, $p < .05$) at fourth grade for the length conservation identity task. Similarly, in the equivalence format length conservation task case, the first grade longitudinal sample subjects were superior to their control group counterparts (means of 4.04 versus 2.50; $t = 4.83$, $df = 70$, $p < .001$) while the converse relationship was true for the fourth grade comparisons (means of 4.96 versus 5.33; $t = 1.25$, $df = 76$, N.S.).

In terms of the overall logical concept task array, it may be concluded that there is minimal evidence for pervasive repeated measurement effects in the subsequent year's assessments.

In similar fashion, analyses of variance were conducted during the third assessment year of the present Piagetian study (the means and standard deviations of the longitudinal and testing control samples are presented in the Appendix). Tables 7 to 11 report the summary values for these analyses. The main considerations (over and above the anticipated

grade-level distinctions that are significant in 23 of the 27 cases; the exceptions include *groupement* VI, some-all understanding, length transitivity, and equivalence conservation of weight) indicate ten cases of assessment condition main effects. Five of these instances produced F values with an associated probability < .01 (*groupements* IV and VIII, class inclusion, cardinality, and equivalence conservation of length). All of these difference contrasts favored the longitudinal sample subjects, i.e., combined grade and sex subsample means of 6.57 versus 5.70 (*groupement* IV), 7.22 versus 6.22 (*groupement* VIII), 4.34 versus 3.77 (class inclusion), 4.07 versus 3.57 (cardinality), and 5.37 versus 4.29 (equivalence conservation of length). In addition, for class inclusion the relative longitudinal and testing control group differences were most notable at the younger age levels (mean differences of 1.11, .40, and .27 for the second, fifth, and eighth grades, respectively; testing condition x grade level interaction F = 3.42, df 2, 202, p < .05), and these distinctions were more evident for males at the second and fifth grade levels and for females at the second and eighth grade levels (i.e., testing condition x grade level x sex interaction F = 6.71, df 2, 202, p < .01).

Primary Results

Analyses of variance. Tables 12 to 17 present the means and associated standard deviations for the various *groupement* scores, the traditional Piagetian measures, and the three short-term memory tests for each age-grade level across the four assessment years. The mixed model: factorial ANOVA summaries (between-subject factors of sex and grade level, and within-subject factor of assessment year 1 to 4) are shown in Tables 18 through 22. Table 18

presents the various *groupements* contrast results and reveals significant grade-level main effects for all the subscore measures and a notable absence of gender distinction main effects. No grade x sex interactions approached significance. Year of assessment main effects, as anticipated, were significant for all 14 of the score and variable combinations. While assessment year x sex interaction values were uniformly nonsignificant, a sizeable number of assessment year x grade level interactions were significant (11 of the 14 F values have an associated probability < .05). These grade x assessment year interactions reflect the varying difficulty patterns within the *groupement* battery as evidenced in differential growth for certain grades selectively for certain between assessment year contrasts. This is shown in greater detail in the trend analyses section that follows. The counterpart ANOVAS for the remaining cognitive measures administered to the entire subject sample over the four-year interval are presented in Table 19. Grade level main effects are significant for all 5 cases. There was a marginal superiority present for female class inclusion performances and these differences were more notable for the initial assessment years (i.e., male and female combined grade mean differences of .51, .26, .11, and .03 for the first, second, third, and fourth assessment years, respectively).

Table 20, 21, and 22 presents the ANOVA summaries for the remaining measures that were administered only to the younger cohorts. As expected for the present assessment design grade-level main effects were present for all the indices. In similar fashion significant assessment year main effects were found for the majority of measures (the single exception was transitivity of weight). Sex distinctions were absent. Assessment year x grade-level interactions

were significant for the dichotomous sorting, cardinality, addition, seriation, number, and length (identity condition only) and weight conservation tasks. These latter interactions reflect the joint effects of initial task difficulty patterns and differential growth rates over the present grade and assessment year data points.

Trend analyses. A series of trend analyses via an ANOVA approach were conducted in which the linear, quadratic, and cubic components were orthogonal. Evaluation of higher order interactions with the grade level and sex factors were also provided. These results are summarized in Tables 23 to 27. As noted in the previous data summary section, grade level main effects were significant for all tasks, gender distinctions were notably absent (there is a suggestion of female superiority for the some-all understanding and class inclusion tasks) and no significant grade x sex interactions were observed.

The linear component was significant for all measures except weight transitivity. Significant grade level x linear component interactions ($p < .05$) were observed for 15 cases in the larger sample (N = 134), that is, *groupements* I, II, IV, VI, VIII, all six combined *groupement* cases, class inclusion, combinatorial reasoning, digit memory, and visual memory tasks. For the subsample of younger children (N = 88) similar grade x linear interactions were found for all the conservation tasks, dichotomous sorting, cardinality, arithmetic addition, and the seriation tasks. These expected distinctions in relative developmental rates across the present three target cohorts are exemplified in Figures 1 to 4 with the mean percentage of correct items for *groupement* IV (co-univocal multiplication

of classes), class inclusion, cardinality, and seriation, respectively. No significant sex x linear component interactions were observed.

Significant quadratic components were observed for the following tasks: *groupements* V, VII, and VIII, total class negation, total relations composition, total relations reciprocity, combined relations, combinatorial reasoning, word memory, number conservation, equivalence conservation of length, dichotomous sorting, cardinality, arithmetic addition, and seriation. Interaction values for the grade level x quadratic component were significant for six cases, i.e., combinatorial reasoning, word memory, visual memory, number conservation, cardinality, and arithmetic addition. These significant departures from monotonically increasing functions across the present annual assessment points is graphically represented in Figure 3 (cardinality), Figure 4 (seriation), and Figures 5 to 10 for the *groupement* VII (bi-univocal multiplication of relations), combined classes, combined relations, combinatorial reasoning, word memory, and visual orientation memory tasks, respectively. Two cases for the younger subjects are shown in the patterns for number conservation and equivalence conservation of length (Figures 11 and 12).

Finally, an instance of a significant cubic component was observed in *groupement* II secondary addition of classes (see Table 23 and Figure 13). In addition, the cubic x grade level interactions were significant for the word and digit memory tasks, $p < .05$ (see Table 24).

In summary, as Tables 23 through 27 clearly indicate, the major trend

component for the present concrete operations task array and subject age range is linear. As expected there are also numerous cases of trend component interaction with the age level cohorts. These are shown graphically in the representative figures selected. It is also obvious that the particular developmental growth patterns vary depending upon the tasks or task "clusters" at issue. Thus the patterns shown for the larger sample responses to the class *groupements* (I to IV) are different from those shown for the combined relations counterparts (V to VIII), i.e., compare Figures 6 and 7. General classificatory understanding shows relatively concordant score increases across the present 5 to 13 year old age range, while relations scores start much higher (72 percent versus 49 percent of items passed at the kindergarten level) and show distinct "ceiling" effects by the fifth grade level (see also the pattern for class inclusion performance in Figure 2). In contrast, the younger subsample trend patterns for cardinality (Figure 3) and seriation (Figure 4) are certainly very similar and are in general accord with the concurrence predictions of Piaget and Szeminska (1952); see also Gonchar (1975). In general one would expect much more pronounced growth rates for tasks such as conservation of quantitative invariants in the kindergarten to third grade cohort as compared to the third grade to sixth grade case. This is shown in the cases for number conservation (see Figure 11) and equivalence conservation of length (see Figure 12). There is a 36 percent increase in average number conservation scores for the younger cohort compared to a 5 percent increase

for the older group. Length conservation acquisition appears somewhat later and this is shown in the increase values of 54 percent and 22 percent for the two cohorts, respectively (see Figure 12). (See Footnote 2.)

A representative case of developmental prediction: memory variables and two logical reasoning tasks. It is obvious that inferences concerning the synchrony or asynchrony of developmental emergence of Piagetian logical operations structures are ultimately based upon subjects' performances on tasks designed to embody such cognitive structures. As we have emphasized previously, orthodox Piagetian theory predicts a tight interrelationship among structures and tasks characteristic of a given developmental period or stage, e.g., concrete operations, and a sequential or predictive relationship between tasks derived from adjacent developmental periods, i.e., concrete and formal operations (Hooper, Swinton, & Sipple, 1976). This follows from the basic tenet that, "Inherent in Piaget's general system is the view that the logical structure of mathematical and physical systems is paralleled by the order of psychological (logical thought) development [Beilin, 1971a, p. 116]."

Performance on any series of logical reasoning tasks, however, is apt to reflect sources of variability other than those based upon the presumed underlying cognitive structure, such as stimulus salience, instructional set, response and attentional demands, and short-term memory requirements (see Flavell, 1977, pages 220-235 for a recent discussion of these diagnosis

and related causal inference problems). The present analysis examines the relationships among two measures of auditory memory span, visual orientation memory, and a representative index of the concrete operations period (class inclusion) and of the formal operations period (combinatorial reasoning). Two cross-lagged correlation models are applied to the data to investigate the degree to which causation might be viewed as reciprocal, rather than as flowing strictly from perceptual to logical operation development (Labouvie, 1974). It may be seen that although based on differing assumptions, the causal analyses yield similar results in these data.

Over the three-year period, the most stable instruments were the auditory memory tasks (r = .71, word and .66, digit) followed by visual memory (r = .55) and combinatorial reasoning and class inclusion (r = .41 and .35 respectively). The best single predictor of Piagetian performance three years later was initial status on the visual memory task, yielding slightly, but not significantly greater predictive power than did initial status on the Piagetian performances themselves. Final year combinatorial reasoning performance shared more variance with earlier memory tasks than did class inclusion, but both tasks initially appeared more related to this visual memory task than to auditory span. It should be noted that the present correlation analyses report data for the combined grades (N = 134).

The intercorrelations among the various measures for the time intervals are shown in Table 28. While all variables show significant correlations with age, combinatorial reasoning and visual memory in year one are highly age-related, while digit memory in year two and year four class inclusion

exhibit weak dependence on age ($r < .20$). It should be kept in mind that the age span of the sample, initially 5 to 12 years, and ultimately 8 to 15, inflates correlations with age. For example, while the correlation of year four combinatorial reasoning with age is .43, the nearly 5 to 1 ratio of standard deviations results in a raw regression coefficient of combinatorial reasoning on age of only .08; that is, it requires about a one year difference in age to result in a one-point predicted increment on the year four combinatorial reasoning task.

To allow for the possibility that relationships among tasks might be artifacts of mutual age-dependence, age was allowed to enter the regression equations used to predict final status on the two reasoning tasks from previous years' levels on reasoning and memory tasks. As Table 29 reveals, the inclusion of the age variable inflates the regression weights for the other variables in predicting class inclusion, but acting as a suppressor variable deflates the impact of other predictors of combinatorial reasoning. In none of the predictive regression equations, however, does the addition of age cause the contribution of the other variables to fall below significance. On the other hand, in the case of predicting final combinatorial reasoning from year one status, the addition of auditory and visual memory, the only two significant task variables, raises the multiple r only .06 from the correlation (.43) obtained from age alone, suggesting that much of the variance in the system can be explained by age-dependence.

Examining the standardized regression weights of the variables from each year entering significantly into the prediction of final level on reasoning tasks, and the resulting multiple correlations, it is apparent

that combinatorial reasoning is uniformly more predictable from previous years tasks than is class inclusion. However, class inclusion appears somewhat more stable, in that in all three prediction equations, earlier levels of performance on this task are significant predictors of final status, while knowledge of initial level on combinatorial reasoning does not add significantly to the prediction of final combinatorial reasoning status attainable from year one word memory span and visual memory. Furthermore, in years two and three, class inclusion enters as a significant predictor of combinatorial reasoning, but combinatorial reasoning never predicts class inclusion. There is no support for the hypothesis that the more visual combinatorial reasoning task would be better predicted by previous levels of visual memory, while class inclusion would be better predicted by the verbal digit or word memory span tasks. Only in the concurrent year four analyses, in which the variables are of course not included as "predictors" of themselves, is there some indication that combinatorial reasoning is more related to visual memory, although each reasoning task is concurrently linked to one of the auditory memory variables. For both reasoning tasks, over the three years of predictions, predictors shift from visual memory to auditory memory as supplements of the earlier levels of the reasoning tasks themselves.

The concurrent year four regressions, suggesting a word memory span component for class inclusion and digit span and visual memory requirements for combinatorial reasoning, do serve to underscore the fact that neither task is a "pure" measure of a logical operation, and remind us that it is impossible to operationalize the measurement of an hypothesized structure

without introducing performance variance. Thus, one might agree that the relative difficulty of the two logical operations might better be determined by first predicting scores on each from a knowledge of subjects' previous and concurrent levels on perceptual tasks with which the reasoning tasks share method variance, but which are clearly not measures of the cognitive structures of interest.

The residuals from these predictions might then be thought of as measures of attainment on the logical tasks with "irrelevant" variance stripped away. This use of memory variables as covariates is reasonable if in fact they represent a capacity or substrate for the development of logical operations. If, on the other hand, the perceptual skills are to some extent resultants of developing logical operations skills, removing their apparent contribution will, if reliability of measurement is sufficient, overcorrect, taking out variance properly attributable to the logical tasks. In particular, while the year four combinatorial reasoning with class inclusion correlation is .45, the partial correlation with digit memory and visual memory taken into account is .33.

Attribution of cause from correlational evidence is an area where angels traditionally fear to tread. Two approaches, both described by Kenny (1973, 1975), were applied to these data in an attempt to tease out direction of developmental influence. The first, presented in the 1973 volume, Structural Equation Models in the Social Sciences, and elaborated in a 1975 article, corrects the synchronous and lagged correlations of two variables for presumed changes in reliability over time. If a variable is more reliable at time 2, it will be easier to predict, making it look more like an effect

than it should. Changes in reliability are inferred from the pattern of correlations of the variables with other variables measured at the two points in time. The assumption is made that variables are moving in time as a rigid system, that is, that variables are neither approaching nor receding from one another in the observation space. Thus, the corrected synchronous correlations should be approximately equal if the assumptions hold. In this case, four other variables were available to obtain independent estimates of K_x, the ratio of the reliabilities of variable x at time t_2 to t_1. Tables 30, 31, and 32 show the observed and corrected correlations and corresponding values of K for the logical tasks and visual memory for all adjacent years, and for other predictors of year four logical tasks in the years in which they played significant roles in the regression equations.

Observing the adjacent-year cross-lagged correlations between visual memory and class inclusion (Table 30), we see that the "quasi stationarity" assumption of equal corrected synchronous correlations is met quite satisfactorily for the first two year, but that the corrected cross-lagged correlations are not sufficiently discrepant to lead to any inference concerning the direction of causality. From years three to four, the communality method leads to a marked estimated drop in the reliability of the class inclusion measure, making the corrected cross-lagged correlations more discrepant than the observed values.

The difference, suggesting a tendency for changes in class inclusion to be causally prior to changes in memory, barely fails to attain significance at the .05 level ($Z = 1.88$), but in both the analyses for years three to four and

years one to four, corrected synchronous correlations may be too different (.35 versus .31, .39 versus .35) to make the hypothesis of quasi-stationarity appealing.

Turning to the cross-lagged relationships between visual memory and combinatorial reasoning (Table 31), the communality method leads to reliability corrections that attenuate the observed differences in cross-lagged correlations from years one to two and from years two to three, but a sharp increase in the year four estimated reliability of combinatorial reasoning amplifies the excess of $r_{CR_3VM_4}$ over $r_{VM_3CR_4}$ raising the difference to a highly significant level ($Z = 3.38$), and suggesting that growth in combinatorial reasoning leads to growth in visual memory. Since such a developmental influence could hardly alter a fundamental physiological capacity, if we accept this finding, then the most reasonable causal link would seem to be not growth in memory space but a mediational process of change in means and efficiency of memoric encoding due to the emergence of new logical structures. However, the years one to four results, while not significant, are apparently in the opposite direction from those of each of the intervening adjacent years, suggesting that the hypothesis that change is occurring as a motion of a rigid system, with increases and decreases in correlations reflecting only changed reliabilities rather than relative directions of vectors in the system, may not be tenable.

Table 32 presents the observed and reliability-corrected cross-lagged correlations among year four class inclusion and combinatorial performances and those remaining previous years' variables that entered significantly

into the regression equations. The only significant difference among cross lags, $\underline{Z} = 2.28$, occurs for year two class inclusion as a predictor of year four combinatorial reasoning. Again, however, the corrected synchronous correlations, .34 and .40, are sufficiently disparate to call into question the assumption on which the reliability corrections are based, although again, not significantly different with this sample size.

An alternative test offered in Kenny (1973) is based on the availability of additional occasions of measurement rather than of additional variables measured at two occasions. In this approach, reliabilities are not directly manipulated, but loadings on a postulated synchronous common factor and on a lagged factor are assumed to stay in a constant proportion. That is, observation vectors may converge or diverge over time, but they are assumed to do so at a steady rate. Kenny offers three wave causal contrasts in two forms: one form involving synchronous correlations and one only lagged correlations. It is easy to generalize these equations for the solution of four-wave data, and this has been done in Table 33. The first two columns represent the values of the two components of the test based on synchronous correlations. If the value of the left column is significantly more positive than that of the middle column, cause is presumed to flow from x to y. The discrepancy is greatest for CR to VM and in the other direction, from CI to CR, supporting the findings obtained through reliability correction.

However, the fact that small negative values appear for at least one component of each contrast suggests that the synchronous correlations rx_2y_2 and rx_3y_3 are slightly inflated by shared method variance. To the extent

that the negative values are not just due to sampling error, the assumptions of this test can also be questioned. The last column of Table 33, however, offers a test that does not depend on synchronous correlations, being affected by only the factors hypothesized to influence time-lagged correlations. This test in fact does not depend on synchronous data at all, and again leads to the conclusion that combinatorial reasoning exerts a causal influence on the development of visual memory and that class inclusion is developmentally prior to combinatorial reasoning.

Partial correlation, removing covariance predictable from initial status on memory variables, considerably reduced the relationship between the two Piagetian tasks in the final year ($r_{CICR} = .45$, $r_{CICR \cdot VMDM} = .33$), suggesting that short-term memory factors account for a significant portion of the covariance of the two logical operations tasks. Examination of the cross-lagged panel correlations, however, suggests that using the memory variables as "passive" covariates may represent an oversimplification. In each of the 3 adjacent year comparisons, previous level of combinatorial reasoning predicts visual memory at a slightly higher level than visual memory predicts combinatorial reasoning ($r = .47$ vs $.39$, $.32$ vs $.24$, $.41$ vs $.37$). This suggests that visual memory task performance is not merely a background or capacity variable, but may itself be influenced by emerging operational structures. Class inclusion and digit span reveal an inconsistent pattern of direction of influence.

These results make it clear that individual differences in short-term memory development contribute to the relationships of these concrete operations performances. However, the direction of apparent causality between

combinatorial reasoning and visual memory in all years, and with auditory memory from years two to three, suggests that changes in memory performance may also be to some degree a result of the development of cognitive operations. To the extent that the assumptions of these tests are reasonable, the use of memory variables as covariates will be counterindicated, and the development of reciprocal causal models will be necessary to describe these relationships. Recent discussions of the complex interrelationship among memoric processes, metamemory, and cognitive developmental variables support this conclusion (Flavell, 1977; Hagen, Jongeward, & Kail, 1975; Kail & Hagen, 1976; and Piaget & Inhelder, 1973).

That class inclusion influences the emergence of combinatorial reasoning is not surprising. Class inclusion, as conceptualized and measured by Piaget, is one of the more difficult attainments of the concrete operations period, but combinatorial reasoning is necessary to formal operations. The finding of a causal link from combinatorial reasoning to visual memory may be less in accord with intuition or conceptual task analyses. Since McLaughlin (1963), information processing theorists have thought of short term memory as a capacity or working space limiting the complexity of cognitive operations. However, more recent approaches to memory development (for example, see Flavell, 1977, pages 183-218) have emphasized encoding, structuring and retrieval processes and strategies as the entities in which development works its changes, rather than seeing development as the physiological growth of computing space.

Discussion

It is probably worth repeating at this point that the present investigation was concerned with two major contentions within the Piagetian organismic system. These were the fundamental stage properties of integration and structuring and the derivative assumption of developmental synchrony for behavioral patterns putatively native to a particular stage or time period. The specific focus was directed toward the concrete operations period of middle childhood.

Initially, it was seen that continued participation (selective survival) influences were generally absent in the present study. In similar fashion an analysis of repeated measurement biases revealed few significant or consistent effects that would seriously question the longitudinal developmental trends (see, however, footnote 2). As would be expected for the present age and grade range, assessment interval, and concrete operations task arrays, notable developmental trends were evident. Thus, the main effects of age grouping and assessment year were highly significant for almost all of the task comparisons. Significant gender distinctions and sex and condition interactions were notably absent. Moreover, the trend analyses indicated that linear growth patterns were predominantly present in the great majority of the present task cases. Significant quadratic components (14 cases) and cubic components (1 case) highlighted the fact that the slope of the developmental gradients depended upon the age cohort in question. As would be expected growth was most marked for the younger cohorts.

In general, these result patterns are in accord with the expectations derived from both organismic theory a là Piaget and the original Genevan

norms based on cross-sectional data (much of which did not permit direct across-task comparisons). Yet the answer to the critical issue of developmental synchrony versus developmental assynchrony remains equivocal. Numerous cases of developmental task sequences (therefore denoting within-stage assynchrony) are evident. The more notable instances include the following cases. The emergence of classificatory skills in general appears to follow their relational counterparts (although some notable cases of synchrony are also present--see below). This is true for initial levels of mastery and later functional maturity. Thus the four class *groupements* cases were much more difficult than the four relations cases and this was particularly true of the class composition operations. Within the classificatory task domain the "some and all" understanding task was distinctly easier (and therefore an earlier appearing developmental acquisition) than class inclusion, dichotomous sorting, or cardinality. The later three tasks appear to be of generally equivalent difficulty. This relative difficulty pattern agrees with Kofsky's (1966) earlier cross-sectional findings. Performance on the class inclusion task at all age and grade levels seem to exceed mastery of the initial four *groupement* tasks. Within the relations task domain transitive inference (as presently assessed) was much less difficult than seriation or the latter *groupement* task cases (V-VIII). Functional mastery of the seriation tasks appears to follow mastery of the four relations *groupement* cases.

Mastery of identity conservation preceded equivalence conservation (Brainerd & Hooper, 1975, 1978; Hooper, Toniolo, & Sipple, 1978) and each of these followed mastery of the counterpart transitive inference tasks. Within the eight *groupement* cases, as cited above, the class tasks are much

more difficult than the relations tasks. Concerning the complimentary *groupement* operations skills, class composition mastery is much later in appearance when compared to class inversion skills. While these results may be traced to differential verbal demands or semantic understanding requirements of the composition versus the inversion test items (Dihoff, 1976a), they stand in marked contrast to the equivalent difficulty patterns for the relations composition and reciprocity operations items over the present age range.

In contrast to these cases of developmental sequences within the period of concrete operations, a number of developmental concurrences were also observed. Cardinality skills appear to develop in parallel with seriation skills (transitive inference excepted). Class inclusion understanding, cardinality, and dichotomous sorting (the latter involving a consistent and exhaustive classification on each of three attributes) appear to be of equivalent difficulty. Conservation of number, equivalence conservation of length, and equivalence conservation of weight indicate generally similar growth trends. Finally, and somewhat surprisingly, combinatorial reasoning (presumably a measure of early formal operations period concept abilities) and class inclusion reveal very similar developmental patterns.

Insofar as the three short-term memory span tasks are concerned, the means for forward word span exceed those for forward digit span at all age levels and assessment years. Visual orientation memory in contrast to these two auditory cases reveals much more accelerated developmental trends (steeper gradients) and higher mean percentage scores at all grade levels. As covered above in the final portion of the results section, short-term memory functions appear to have a mutually reciprocal developmental relationship with the

present array of logical reasoning tasks.

Concerning the actual validity of developmental stages the following generalizations are in order. One, there is no question that the younger children in the present study (in terms of age and grade level or initial assessment years) approached the logical reasoning tasks in a distinctly different way from that shown by their older counterparts or, indeed, by themselves in the later years of the study. Anyone (including the test administrators employed in the present project) who has questioned a nonconserving (i.e., preoperational stage) child compared to a conserving child knows immediately what these data convey. Of course, if one observes the mean score trends averaged across cohort groups and assessment years one is apt to conclude that developmental progressions are very gradual, indeed, even linear in character. In this regard, one definitive conclusion from the present data is patently obvious, i.e., quantitative and qualitative developmental patterns are not mutually exclusive. Rather, quantitative increments in one domain, e.g., short-term memory facilitate qualitative "leaps" in another area of cognitive functioning. Certainly the converse also holds true--that is a mastery of certain logical skills, e.g., transitive inference appears to "transfer" to a counterpart cognitive domain, e.g., conservation (Hooper, Toniolo, & Sipple, 1978).

What we are left with is a decidedly complex but not uninterpretable picture of cognitive growth. At the initial phase of any developmental period interindividual and intraindividual variability is most notable. Strong relations among task domains are at this time not to be expected. Gradually cognitive abilities emerge and facilitate each other. This would

coincide with Wohlwill's cases of reciprocal interaction or disequilibration/stabilization (see Wohlwill, 1973, pp. 204-236). Eventually the complimentary task domains reveal a decidedly concordant mastery pattern.

The picture of cognitive growth generated by the present study may be depicted by the third case shown in Figure 14. Rather than a simple step function of cognitive growth (Figure 14a) or a modified step function as suggested by Flavell (1971), see Figure 14b, the best approximation would appear to be a sigmoid sequence of stage transitions, see Figure 14c (these figures were originally presented in Feldman & Toulmin, 1976, page 450). If one "expands" this figure of an idealized growth function to include an array of cognitive measures one is immediately impressed with the inherent complexity of the generalized case. Variability coexists with across-task consistency. Still, this fundamentally is the essence of the human condition. Certain abilities grow in rather "lock step" fashion with other abilities while certain of other abilities appear to be the genetic precursors of later appearing higher order cognitive acquisitions. In a very real sense both cognitive consistency and variability are present in this investigation's data.

At a more technical level, the major question of cognitive décalages remains to be resolved. Are the cases of sequences briefly outlined above best considered to be instances of horizontal or vertical décalages? If they are judged to be the former then few problems are raised for general Piagetian theory. If we wish to contend that a genuine vertical décalage was at issue (e.g.,between the general relational versus the general classificatory concept cases) then it remains to be demonstrated on what logical

or psychological grounds this across stage sequence rests (Pinard & Laurendeau, 1969). Recently a new form of task interrelationship, the oblique décalage, has been suggested. This has been described as "indicated in differential achievement between conservation, for example, and classification and ordering tasks, which are informed by common concrete operational structures but different component structures (Beilin, 1976, p. 78, footnote 2)." It would seem that, despite their rather ad hoc basis, oblique décalages are designed to encompass both within and across stage phenomena and thus may be appropriate to the present case. Certainly within-stage developmental concurrences have been observed relatively rarely (see for example, Braine, 1959; Gonchar, 1975; Toussaint, 1974; and a recent review by Flavell, 1977). Indeed, Flavell concludes that nonconcurrence among theoretically related cognitive items is the rule and concurrence relationships the special exception (Flavell, 1977, p. 248).

The possibility exists, of course, that the concrete operations period is perhaps best viewed as a two part sequence with certain earlier appearing abilities or skills (e.g., identity conservation, some-all understanding, and transitive inference) preceding certain later cognitive skills such as those dealing with class inclusion relationships and cardinal number (Pinard & Laurendeau, 1969). But this suggestion brings us full circle to the original issues of horizontal versus vertical décalage; that is, if there is really a two-stage developmental sequence--then what are the logical and functional prerequisites present in one task domain relative to the other? In the case of natural number concepts Piaget's contention that classes and relations are logically coordinate and therefore should be psychologically

parallel achievements is certainly intuitively appealing (Gonchar, 1975). Yet the majority of recent research results (including the present investigation) appears to favor the primordial status of relational concepts over the classificatory cases and thus favor Peano's views over either Piaget or Whitehead & Russell's theories (Brainerd, 1979, 1978a). There does not seem to be any logical or task requirement analysis bases for this earlier emergence of relational as contrasted with classificatory concept acquisitions.

Yet, the general concept of a cognitive stage for the middle childhood behavioral domain may be alive and well in places other than Geneva! Insofar as the concrete operations focus is concerned we agree with the following recent comments:

> Such evidence changes the meaning of "stage" in an interesting way. For a major stage like concrete operations, we might have expected a very brief period of change and transition, during which concrete operations emerge and mature, followed by several years of relative stasis and quiescence, during which the child is more or less stably and unchangeably concrete-operational in his thinking. If, instead, the child actually continues to perfect, generalize, and solidify his grasp of weight conservation throughout most of middle childhood and perhaps also well into adolescence, the stage of concrete operations is all change and transition, with little or no stasis and stability. Thus the stage itself, and not the transition to it, becomes the period of continuous growth and change. Because of this continuous growth and change, one cannot predict the child's responses to concrete-operational tasks merely from the knowledge that he is in the concrete-operational stage, as one could have if being in that stage meant continuing to have essentially the same mental structure for a period of years. This loss of predictability reduces the scientific value of the stage concept, but I do not think it makes it valueless. Suppose that all concrete-operational skills developed concurrently in an interdependent, mutually facilitative fashion. The fact that all these synchronous, closely interacting developments took a long rather than a short time to be completed would not mean that the term "stage" could not be applied meaningfully and usefully to this developmental pattern. We simply would have a more dynamic concept of stage, one that refers to an extended process of concurrent, interdependent developmental changes. Wohlwill thinks the concept of stage is theoretically useful, and the sort of stage he has in mind is of this dynamic sort (Wohlwill, 1973, Chap. 9). [Flavell, 1977, 246-247]

This commentary reinforces the evaluation offered a number of years ago, i.e., "Any monolithic attempt to describe or encompass the totality of cognitive growth from birth to maturity is certain to ignore the immense complexity and inherent spontaneity of man as an intellectual organism or to greatly overestimate our current level of sophistication in the behavioral sciences (Sigel & Hooper, 1968, p. 5)."

The final evaluation of the present normative investigation leads one to a "compromise" conclusion. While developmental synchrony was more evident in the initial and final assessment years for the younger age cohorts (ranging from six to eleven years of age), the transition from preoperational forms of logical reasoning to a full mastery of the logical *groupements* specified by Piaget as underlying the concrete operations period appears not to be a punctate, discontinuous episode in the child's life. Rather, the acquisition of concrete operations appears to involve an extended developmental process marked by unevenness and "reciprocal interweaving" among the supposedly unitary logical concept domains. However, instead of prematurely rejecting stages at this point, we prefer to consider the stage construct as an heuristic device for guiding our future research efforts and associated theoretical speculations. Thus the primary question concerns what modifications are necessary in the Piagetian concrete operations stage "designation" to permit it to play a continued role as a potential explanatory construct but in more complete accord with developmental reality.

Footnotes

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[2]It is clear that the present trend analyses may be biased to unknown degrees by repeated testing effects and cohort distinctions (or, most likely a combination of these interactive influences). In order to "adjust" the individual child's performance patterns to account for these potentially

biasing influences a special correction procedure was employed. This method and the associated results, which are reported in detail in Hooper, Sipple, & Swinton (in preparation), adjusts each individual's score to remove both retest bias and cohort differences. The resulting scores represent performances that would have been obtained if an actual full-range longitudinal study had been undertaken and no retest biases were present. The corrected trend analysis are reported in Hooper, Sipple, & Swinton (in preparation), and a representative case for class inclusion reasoning scores is shown in Figure 15.

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Table 1

SAMPLING DESIGN FOR THE LONGITUDINAL STUDY

(Underlined entries are approximate mean ages and arrows represent continuity of subgroups)

	Time of Measurement			
Year of Birth	1973	1974	1975	1976
1967	6 (N = 60) [Kindergarten]	→ 7 (N = 48)	→ 8 (N = 46)	→ 9 (N = 41)
1967		7 (N = 24)		
1967			8 (N = 20)	
1964	9 (N = 60) [Third Grade]	→ 10 (N = 54)	→ 11 (N = 50)	→ 12 (N = 47)
1964		10 (N = 24)		
1964			11 (N = 22)	
1961	12 (N = 60) [Sixth Grade]	→ 13 (N = 54)	→ 14 (N = 52)	→ 15 (N = 46)
1961		13 (N = 24)		
1961			14 (N = 24)	

Table 2

Analysis of Variance Summary for the *Groupament* Tasks with Three Factors: Assessment Condition (Longitudinal versus Testing Control Subjects), Grade Level (First, Fourth, and Seventh), and Sex

	Sources of Variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Groupament I	3.34	1.46	34.10	14.94[c]	1.01	.44	1.53	.67	1.30	.57	.01	.00	.53	.23	2.28
Groupament II	6.52	2.69	32.58	13.43[c]	.74	.31	.41	.17	.09	.04	3.18	1.31	1.38	.57	2.42
Groupament III	8.76	1.78	14.20	2.88	4.25	.86	1.96	.40	.49	.10	9.00	1.82	.20	.04	4.93
Groupament IV	17.20	3.34	56.50	10.99[c]	2.83	.55	5.18	1.01	1.67	.32	16.13	3.14[b]	4.51	.88	5.14
Combined *Groupaments I-IV*	131.98	3.89[b]	497.56	14.65[c]	.27	.01	20.41	.60	2.03	.06	70.01	2.06	11.15	.33	33.97
Groupament V	.28	.23	4.49	3.69[b]	2.29	1.88	1.21	.99	.02	.02	.23	.19	1.75	1.44	1.22
Groupament VI	.23	.17	15.68	11.48[c]	.03	.02	.56	.41	4.52	3.31	.46	.33	.78	.57	1.37
Groupament VII	2.52	1.08	14.74	6.33[c]	.22	.09	.31	.14	.01	.00	1.13	.49	2.33	1.01	2.33
Groupament VIII	.05	.03	33.18	17.20[c]	.03	.01	.85	.44	4.49	2.23	.02	.01	.76	.39	1.93
Combined *Groupaments V-VIII*	3.47	.31	235.22	20.70[c]	5.41	.48	9.67	.85	19.97	1.76	.07	.01	14.79	1.30	11.36

a Degrees of Freedom: Assessment Condition = 1, Grade = 2, Sex = 1, Condition x Grade = 2, Condition x Sex = 1, Grade x Sex = 2, Condition x Grade x Sex = 2, Error = 216.

b $p < .05$

c $p < .01$

Table 3

Analyses of Variance Summary for Class Inclusion, Combinatorial Reasoning Task, Auditory Memory Span, Auditory Sequential Memory, and Visual Orientation Memory with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (First, Fourth, and Seventh), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Class Inclusion	5.99	3.59	20.86	12.51[c]	.00	.00	.05	.03	.87	.52	.39	.23	.02	.01	1.67
Combinatorial reasoning	50.32	1.07	1310.45	27.98[c]	.35	.01	31.55	.67	2.41	.05	37.00	.79	1.28	.03	46.84
Auditory memory span	41.93	.42	1951.77	19.69[c]	3.78	.04	108.69	1.10	34.11	.34	214.92	2.17	51.32	.52	99.11
Auditory sequential memory	58.39	.32	1770.04	9.71[c]	101.96	.56	243.56	1.34	.18	.00	20.90	.11	55.59	.30	182.35
Visual orientation memory	1.27	.14	551.13	61.12[c]	.22	.02	11.25	1.25	9.22	1.02	27.60	3.06[b]	13.89	1.54	9.02

[a]Degrees of freedom: Assessment condition = 1, Grade = 2, Sex = 1, Condition x Grade = 2, Condition x Sex = 1, Grade x Sex = 2, Condition x Grade x Sex = 2, Error = 216.

[b]$p < .05$

[c]$p < .01$

Table 4

Analyses of Variance Summary for the Some-All, Dichotomous Sorting, Cardinality, and Arithmetic Addition Tasks with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (First and Fourth), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Some-All	.06	.24	3.05	12.86[c]	.01	.05	.16	.66	.12	.50	.01	.03	.10	.44	.24
Dichotomies	.07	.12	20.14	35.77[c]	1.13	2.00	.85	1.51	1.16	2.07	.25	.45	.04	.08	.56
Cardinality	.48	.39	52.37	43.21[c]	.10	.08	3.23	2.67	1.61	1.32	.46	.38	.46	.38	1.21
Arithmetic addition	.02	.00	119.04	18.82[c]	13.59	2.15	.04	.01	3.17	.50	5.69	.90	2.74	.43	6.32

[a] Degrees of freedom: Assessment condition, Grade, Sex, Condition x Grade, Condition x Sex, Grade x Sex, Condition x Grade x Sex = 1; Error = 142.

[b] $p < .05$

[c] $p < .01$

Table 5

Analyses of Variance Summary for the Seriation, Length Transitivity, and Weight Transitivity Tasks with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level, and Sex (First and Fourth)

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Seriation	1.82	2.11	55.88	64.87[c]	1.22	1.41	1.17	1.36	1.22	1.41	1.60	1.86	.40	.47	.86
Transitivity of length	1.39	.58	56.25	23.64[c]	.02	.01	1.12	.47	.63	.27	.30	.13	.16	.07	2.38
Transitivity of weight	.00	.00	4.32	4.50[b]	1.54	1.60	.09	.09	.08	.09	4.25	4.42[b]	.03	.03	.96

[a]Degrees of freedom: Assessment condition, Grade, Sex, Condition x Grade, Condition x Sex, Grade x Sex, Condition x Grade x Sex = 1; Error = 142.

[b]$p < .05$

[c]$p < .01$

Table 6

Analyses of Variance Summary for the Number Conservation, Length Conservation, and Weight Conservation Tasks with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (First and Fourth), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Conservation of number	3.32	1.17	96.80	34.26[c]	.02	.01	3.28	1.16	1.10	.39	.28	.10	.03	.01	2.83
Identity conservation of length	.78	.33	75.87	32.51[c]	1.58	.68	15.13	6.48[b]	.00	.00	1.53	.66	.28	.12	2.33
Equivalence conservation of length	11.09	2.18	117.03	23.01[c]	3.90	.77	28.61	5.63[b]	3.90	.77	.15	.03	2.28	.45	5.09
Identity conservation of weight	7.75	2.79	46.91	16.87[c]	.49	.18	.99	.36	8.22	2.96	1.96	.70	.04	.02	2.78
Equivalence conservation of weight	12.76	2.32	63.98	11.61[c]	1.27	.23	.31	.06	.42	.08	4.95	.90	3.06	.56	5.51

[a] Degrees of freedom: Assessment condition, Grade, Sex, Condition x Grade, Condition x Sex, Grade x Sex, Condition x Grade x Sex = 1; Error = 142.

[b] $p < .05$

[c] $p < .01$

Table 7

Analyses of Variance Summary for the *Groupement* Tasks with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (Second, Fifth, and Eighth), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Groupement I	.24	.09	58.73	23.09[c]	4.31	1.69	4.75	1.87	2.89	1.14	.83	.33	2.82	1.11	2.54
Groupement II	.12	.05	51.95	21.32[c]	10.22	4.19[b]	1.17	.48	7.55	3.10	.23	.10	2.58	1.06	2.44
Groupement III	3.03	.60	86.35	17.00[c]	1.58	.31	6.65	1.31	5.61	1.10	.42	.08	13.76	2.71	5.08
Groupement IV	34.31	8.03[c]	71.36	16.70[c]	1.87	.44	3.35	.78	3.41	.80	9.40	2.20	19.34	4.52[b]	4.27
Combined *Groupements* I-IV	59.89	1.82	1034.63	31.43[c]	26.64	.81	45.01	1.37	24.69	.75	12.49	.38	121.04	3.68[b]	32.92
Groupement V	1.63	1.74	8.09	8.61[c]	.00	.00	1.02	1.09	1.32	1.41	1.48	1.58	1.74	1.85	.94
Groupement VI	.60	.49	2.69	2.19	1.11	.90	.37	.30	.01	.01	.19	.15	.49	.40	1.23
Groupement VII	9.68	5.12[b]	9.54	5.05[c]	5.76	3.04	2.15	1.14	1.79	.95	12.70	6.72[c]	3.67	1.94	1.89
Groupement VIII	16.58	10.02[c]	33.43	20.20[c]	8.65	5.23[b]	1.33	.80	1.07	.65	2.67	1.61	1.74	1.05	1.65
Combined *Groupements* V-VIII	59.01	6.07[b]	166.24	17.11[c]	41.73	4.29[b]	7.93	.82	.93	.10	13.24	1.36	3.41	.35	9.72

[a]Degrees of freedom: Assessment condition = 1, Grade = 2, Sex = 1, Condition x Grade = 2, Condition x Sex = 1, Grade x Sex = 2, Condition x Grade x Sex = 2, Error = 202.

[b]$p < .05$

[c]$p < .01$

Table 8

Analyses of Variance Summary for Class Inclusion, Combinatorial Reasoning Task, Auditory Memory Span, Auditory Sequential Memory, and Visual Orientation Memory with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (Second, Fifth, and Eighth), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Class inclusion	15.14	15.69[c]	19.45	20.16[c]	.16	.17	3.12	3.24[b]	.64	.66	.04	.05	6.47	6.71[c]	.96
Combinatorial reasoning	24.52	.62	1563.72	39.31[c]	72.34	1.82	169.35	4.26[b]	3.16	.08	70.12	1.76	49.55	1.25	39.76
Auditory memory span	59.29	.66	3591.05	40.22[c]	62.50	.70	54.34	.61	5.46	.06	323.49	3.62[b]	13.71	.15	89.28
Auditory sequential memory	51.10	.31	4824.40	29.56[c]	52.12	.32	147.88	.91	11.10	.07	318.88	1.95	6.02	.04	163.20
Visual orientation memory	17.58	2.22	244.63	30.93[c]	69.21	8.75[c]	27.50	3.48[b]	2.52	.32	19.79	2.50	6.23	.79	7.91

[a]Degrees of freedom: Assessment condition = 1, Grade = 2, Sex = 1, Condition x Grade = 2, Condition x Sex = 1, Grade x Sex = 2, Condition x Grade x Sex = 2; Error = 202

[b]$p < .05$

[c]$p < .01$

Table 9

Analyses of Variance Summary for the Some-All, Dichotomous Sorting, Cardinality, and Arithmetic Addition Tasks with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (Second and Fifth), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Some-All	.32	2.81	.02	.16	.32	2.85	.10	.87	.02	.20	.30	2.63	.13	1.11	.11
Dichotomies	2.28	4.75[b]	16.89	35.17[c]	.08	.16	1.02	2.12	2.58	5.37[b]	.45	.93	.02	.04	.48
Cardinality	7.70	7.30[c]	12.30	11.67[c]	.04	.04	1.92	1.82	.70	.66	.27	.25	.22	.21	1.05
Arithmetic addition	2.95	.88	33.69	10.05[c]	2.66	.79	4.04	1.20	1.77	.53	1.79	.54	4.68	1.40	3.35

[a]Degrees of freedom: Assessment condition, Grade, Sex, Condition x Grade, Condition x Sex, Grade x Sex, Condition x Grade x Sex = 1; Error = 130.

[b]$p < .05$

[c]$p < .01$

Table 10

Analyses of Variance Summary for the Seriation, Length Transitivity, and Weight Transitivity Tasks with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (Second and Fifth), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Seriation	4.27	5.51[b]	14.92	19.23[c]	.49	.63	.65	.84	.31	.40	.00	.00	.04	.05	.78
Transitivity of length	2.08	.77	7.76	2.88	5.58	2.08	.20	.08	2.52	.94	7.19	2.67	9.40	3.49	2.69
Transitivity of weight	.76	.51	10.30	6.84[c]	5.57	3.70	3.65	2.42	.00	.00	1.75	1.16	1.21	.81	1.51

[a]Degrees of freedom: Assessment condition, Grade, Sex, Condition x Grade, Condition x Sex, Condition x Grade x Sex = 1; Error = 130.

[b]$p < .05$

[c]$p < .01$

Table 11

Analyses of Variance Summary for the Number Conservation, Length Conservation, and Weight Conservation Tasks with Three Factors: Assessment Condition (Longitudinal Versus Testing Control Subjects), Grade Level (Second and Fifth), and Sex

	Sources of variance[a]														
	Condition		Grade		Sex		Condition x Grade		Condition x Sex		Grade x Sex		Condition x Grade x Sex		Error
Variable	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS	F value	MS
Conservation of number	3.91	2.81	5.44	3.92[b]	1.50	1.08	.00	.00	8.72	6.27[b]	.64	.46	.87	.62	1.39
Identity conservation of length	9.52	5.49[b]	19.63	11.32[c]	3.99	2.30	.06	.03	1.12	.64	.13	.08	7.23	4.17[b]	1.73
Equivalence conservation of length	34.30	11.04[c]	20.24	6.51[b]	1.62	.52	2.30	.74	.01	.00	.89	.29	.00	.00	3.11
Identity conservation of weight	6.53	2.47	22.92	8.66[c]	6.48	2.45	.00	.00	4.21	1.59	.35	.13	.30	.11	2.65
Equivalence conservation of weight	7.91	1.75	3.99	.88	8.23	1.82	14.73	3.27	6.52	1.45	6.10	1.35	.20	.04	4.51

[a] Degrees of freedom: Assessment condition, Grade, Sex, Condition x Grade, Condition x Sex, Grade x Sex, Condition x Grade x Sex = 1; Error = 130.

[b] $p < .05$

[c] $p < .01$

Table 12

Means and Standard Deviations for the Four Class *Groupement* Tasks for Subjects Assessed in all Four Years

Assessment year and grade	*Groupements* I		II		III		IV		Total class	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First year										
Kindergarten										
Males (n = 21)	3.76	1.37	4.43	1.69	3.05	1.07	3.67	1.39	14.90	2.95
Females (n = 20)	4.70	1.42	4.80	1.94	3.35	1.87	3.85	2.18	16.70	5.22
Total (n = 41)	4.22	1.46	4.61	1.80	3.20	1.50	3.76	1.80	15.78	4.26
Third										
Males (n = 22)	4.46	1.06	4.68	1.36	3.18	2.26	4.14	1.94	16.45	4.65
Females (n = 25)	4.48	1.12	4.52	1.01	3.32	2.46	5.08	2.22	17.40	4.07
Total (n = 47)	4.47	1.08	4.60	1.17	3.26	2.35	4.64	2.12	16.96	4.33
Sixth										
Males (n = 21)	5.86	1.42	5.91	1.55	4.29	2.05	6.43	1.47	22.48	4.97
Females (n = 25)	6.36	1.22	6.56	1.36	4.76	2.55	6.32	2.38	24.00	5.52
Total (n = 46)	6.13	1.33	6.26	1.47	4.54	2.33	6.37	1.99	23.30	5.27
Combined grades										
Males (n = 64)	4.69	1.54	5.00	1.64	3.50	1.93	4.73	2.00	17.92	5.34
Females (n = 70)	5.21	1.50	5.33	1.70	3.84	2.41	5.17	2.44	19.56	5.92
Total (n = 134)	4.96	1.54	5.17	1.68	3.68	2.19	4.96	2.25	18.78	5.69
Second year										
First										
Males (n = 21)	4.62	.92	4.95	1.36	3.38	2.31	4.43	2.48	17.32	5.32
Females (n = 20)	4.95	1.19	5.10	1.52	3.90	2.15	4.15	2.25	18.10	5.19
Total (n = 41)	4.78	1.06	5.02	1.42	3.63	2.22	4.29	2.35	17.73	5.20
Fourth										
Males (n = 22)	5.68	1.73	5.50	1.63	4.18	2.09	6.41	1.76	21.77	6.06
Females (n = 25)	5.56	1.69	5.56	1.56	3.96	2.07	5.60	2.50	20.68	6.14
Total (n = 47)	5.62	1.69	5.53	1.57	4.06	2.06	5.98	2.20	21.19	6.06
Seventh										
Males (n = 21)	6.19	1.60	6.38	1.60	4.19	2.06	6.76	1.92	23.52	5.60
Females (n = 25)	6.36	1.66	6.60	1.63	5.52	2.18	6.92	1.91	25.40	5.99
Total (n = 46)	6.28	1.62	6.50	1.60	4.91	2.21	6.85	1.90	24.54	5.83
Combined grades										
Males (n = 64)	5.50	1.58	5.61	1.62	3.92	2.16	5.88	2.29	20.91	6.15
Females (n = 70)	5.67	1.63	5.80	1.67	4.50	2.24	5.66	2.47	21.63	6.49
Total (n = 134)	5.59	1.61	5.71	1.64	4.22	2.21	5.76	2.38	21.28	6.32

Table 12

(cont)

Assessment year and grade	Groupements								Total class	
	I		II		III		IV			
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Third year										
Second										
Males (n = 21)	5.24	1.48	4.86	1.11	3.38	1.96	5.14	2.63	18.62	4.97
Females (n = 20)	5.35	1.57	4.60	1.39	4.05	2.26	5.35	2.30	19.35	4.92
Total (n = 41)	5.29	1.50	4.73	1.25	3.71	2.11	5.24	2.45	18.98	4.90
Fifth										
Males (n = 22)	5.82	1.71	5.82	1.59	4.46	2.09	7.05	1.21	23.14	5.38
Females (n = 25)	5.52	1.81	5.72	1.75	3.96	2.41	6.72	2.39	21.92	6.79
Total (n = 47)	5.66	1.75	5.77	1.66	4.19	2.25	6.87	1.92	22.49	6.14
Eighth										
Males (n = 21)	6.38	1.69	6.38	1.80	5.19	2.80	7.05	1.66	25.00	6.70
Females (n = 25)	6.72	1.49	6.68	1.57	5.96	2.35	7.24	1.42	26.60	5.93
Total (n = 46)	6.57	1.57	6.54	1.67	5.61	2.57	7.15	1.52	25.87	6.27
Combined grades										
Males (n = 64)	5.81	1.67	5.69	1.63	4.34	2.39	6.42	2.09	22.27	6.24
Females (n = 70)	5.90	1.72	5.74	1.78	4.70	2.50	6.51	2.18	22.86	6.63
Total (n = 134)	5.86	1.69	5.72	1.70	4.53	2.45	6.47	2.13	22.57	6.43
Fourth year										
Third										
Males (n = 21)	5.29	1.27	5.57	1.54	4.52	1.99	6.48	2.23	21.86	4.75
Females (n = 20)	5.50	1.61	5.85	1.69	4.20	2.46	6.20	2.40	21.75	6.00
Total (n = 41)	5.39	1.43	5.71	1.60	4.37	2.21	6.34	2.29	21.80	5.33
Sixth										
Males (n = 22)	7.00	1.45	7.09	1.45	4.27	2.12	7.59	1.05	25.95	4.42
Females (n = 25)	6.32	1.87	6.32	1.89	5.20	2.18	7.00	2.02	24.84	6.41
Total (n = 47)	6.64	1.70	6.68	1.72	4.77	2.18	7.28	1.65	25.36	5.54
Ninth										
Males (n = 21)	6.67	1.49	6.71	1.52	5.57	2.34	7.52	1.25	26.48	5.55
Females (n = 25)	7.44	1.12	7.36	1.41	6.16	2.01	7.60	1.12	28.56	4.84
Total (n = 46)	7.09	1.35	7.07	1.48	5.89	2.16	7.57	1.17	27.61	5.22
Combined grades										
Males (n = 64)	6.33	1.57	6.47	1.61	4.78	2.19	7.20	1.64	24.78	5.27
Females (n = 70)	6.49	1.73	6.56	1.77	5.26	2.31	6.99	1.94	25.29	6.32
Total (n = 134)	6.41	1.65	6.52	1.69	5.03	2.26	7.09	1.80	25.04	5.82

Table 13

Means and Standard Deviations for the Four Relations *Groupement* Tasks for Subjects Assessed in all Four Years

Assessment year and grade	*Groupements* V		VI		VII		VIII		Total relations	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First year										
Kindergarten										
Males (n = 21)	6.24	1.64	6.38	1.88	5.24	2.21	5.05	1.94	22.90	5.30
Females (n = 20)	6.40	1.60	6.10	2.05	5.35	2.32	5.05	1.73	22.90	5.47
Total (n = 41)	6.32	1.60	6.24	1.95	5.29	2.24	5.05	1.82	22.90	5.31
Third										
Males (n = 22)	6.82	1.56	7.86	.47	6.32	2.06	6.27	1.52	27.27	4.10
Females (n = 25)	7.16	1.25	7.64	1.11	5.80	2.45	6.04	1.90	26.64	3.86
Total (n = 47)	7.00	1.40	7.75	.87	6.04	2.27	6.15	1.72	26.94	3.94
Sixth										
Males (n = 21)	7.76	.62	7.57	1.21	6.71	1.27	6.91	1.34	28.95	2.96
Females (n = 25)	7.08	1.80	7.56	1.26	6.76	1.51	6.76	1.48	28.16	4.11
Total (n = 46)	7.39	1.42	7.57	1.22	6.74	1.39	6.83	1.40	28.52	3.61
Combined grades										
Males (n = 64)	6.94	1.48	7.28	1.44	6.09	1.97	6.08	1.77	26.39	4.88
Females (n = 70)	6.91	1.58	7.17	1.61	6.01	2.17	6.01	1.82	26.11	4.89
Total (n = 134)	6.93	1.52	7.22	1.53	6.05	2.07	6.05	1.79	26.25	4.87
Second year										
First										
Males (n = 21)	7.48	.87	7.24	1.97	6.52	1.72	6.14	1.85	27.38	4.41
Females (n = 20)	6.80	1.79	6.65	1.76	6.35	2.03	6.00	1.69	25.80	3.53
Total (n = 41)	7.15	1.42	6.95	1.87	6.44	1.86	6.07	1.75	26.61	4.69
Fourth										
Males (n = 22)	7.55	1.10	7.86	.35	7.32	1.04	6.77	1.31	29.50	2.60
Females (n = 25)	7.28	1.02	7.36	1.32	7.16	1.21	6.64	1.50	28.44	2.79
Total (n = 47)	7.40	1.06	7.60	1.01	7.23	1.13	6.70	1.40	28.94	2.72
Seventh										
Males (n = 21)	7.43	1.08	7.91	.44	6.86	2.08	7.48	.87	29.67	3.29
Females (n = 25)	7.72	.68	7.92	.40	7.16	1.49	7.28	1.17	30.08	2.74
Total (n = 46)	7.59	.88	7.91	.41	7.02	1.77	7.37	1.04	29.89	2.98
Combined grades										
Males (n = 64)	7.48	1.01	7.67	1.20	6.91	1.67	6.80	1.48	28.86	3.00
Females (n = 70)	7.30	1.24	7.36	1.33	6.93	1.60	6.69	1.52	28.27	3.88
Total (n = 134)	7.39	1.14	7.51	1.27	6.92	1.63	6.74	1.50	28.55	3.74

Table 13

(cont)

Assessment year and grade	Groupements V $\bar{X}$	V SD	VI $\bar{X}$	VI SD	VII $\bar{X}$	VII SD	VIII $\bar{X}$	VIII SD	Total relations $\bar{X}$	Total relations SD
Third year										
Second										
Males (n = 21)	7.33	1.15	7.33	1.35	7.33	1.28	7.00	.89	29.00	2.63
Females (n = 20)	7.20	1.51	7.30	1.30	6.60	1.57	5.75	1.97	26.85	4.42
Total (n = 41)	7.27	1.33	7.32	1.31	6.98	1.46	6.39	1.63	27.95	3.73
Fifth										
Males (n = 22)	7.86	.47	7.82	.85	7.36	1.36	7.68	.57	30.73	2.03
Females (n = 25)	7.52	1.05	7.48	1.61	7.76	.60	7.48	.96	30.24	2.20
Total (n = 47)	7.68	.84	7.64	1.31	7.57	1.04	7.57	.80	30.47	2.12
Eighth										
Males (n = 21)	7.81	.51	7.81	.68	7.48	1.12	7.48	1.17	30.57	2.68
Females (n = 25)	7.84	.47	7.68	1.25	7.64	1.04	7.52	1.16	30.68	3.30
Total (n = 46)	7.83	.49	7.74	1.02	7.57	1.07	7.50	1.15	30.63	3.00
Combined grades										
Males (n = 64)	7.67	.80	7.66	1.01	7.39	1.24	7.39	.94	30.11	2.54
Females (n = 70)	7.54	1.07	7.50	1.39	7.39	1.20	7.00	1.58	29.63	3.69
Total (n = 134)	7.60	.95	7.58	1.22	7.39	1.21	7.19	1.32	29.75	3.20
Fourth year										
Third										
Males (n = 21)	7.24	1.22	7.95	.22	6.91	1.79	6.86	1.49	28.95	3.43
Females (n = 20)	7.60	.88	7.80	.70	7.25	1.48	6.45	1.70	29.10	3.52
Total (n = 41)	7.42	1.07	7.88	.51	7.07	1.63	6.66	1.59	29.02	3.43
Sixth										
Males (n = 22)	7.91	.43	8.00	.00	7.50	1.19	7.59	.85	31.00	2.05
Females (n = 25)	7.36	1.08	8.00	.00	7.40	.96	7.00	1.44	29.76	2.63
Total (n = 47)	7.62	.87	8.00	.00	7.45	1.06	7.28	1.23	30.34	2.43
Ninth										
Males (n = 21)	7.76	.62	7.86	.65	7.57	1.25	7.24	1.22	30.43	2.84
Females (n = 25)	7.60	1.00	8.00	.00	7.64	1.11	7.40	1.76	30.64	3.63
Total (n = 46)	7.67	.84	7.94	.44	7.61	1.16	7.33	1.52	30.54	3.26
Combined grades										
Males (n = 64)	7.64	.86	7.94	.39	7.33	1.44	7.23	1.23	30.14	2.91
Females (n = 70)	7.51	.99	7.94	.38	7.44	1.18	6.99	1.66	29.89	3.29
Total (n = 134)	7.58	.93	7.94	.38	7.39	1.30	7.10	1.47	30.01	3.10

Table 14

Means and Standard Deviations for Class Inclusion, Combinatorial Reasoning, Auditory Memory Span Test, Auditory Sequential Memory Test, and Visual Orientation Memory Test for Subjects Assessed in all Four Years

Assessment year and grade	CI		CR		AMS		ASM		VOM	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First year										
Kindergarten										
Males (n = 21)	2.10	1.45	6.81	6.38	23.76	4.73	22.38	10.19	9.33	3.31
Females (n = 20)	3.15	1.42	9.00	8.02	24.90	10.10	24.30	13.98	8.50	2.24
Total (n = 41)	2.61	1.51	7.88	7.22	24.32	7.74	23.32	12.07	8.93	2.83
Third grade										
Males (n = 22)	3.68	.99	18.41	8.20	30.59	7.99	29.91	9.88	13.41	3.08
Females (n = 25)	3.72	1.24	19.52	8.82	30.04	10.54	26.92	10.64	13.24	3.64
Total (n = 47)	3.70	1.12	19.00	8.46	30.30	9.34	28.32	10.29	13.32	3.36
Sixth grade										
Males (n = 21)	4.10	1.18	23.24	7.00	33.57	10.41	34.48	10.36	16.95	1.83
Females (n = 25)	4.44	.92	24.76	6.98	35.44	9.31	35.60	11.73	17.76	2.09
Total (n = 46)	4.28	1.05	24.07	6.96	34.59	9.76	35.09	11.02	17.39	1.99
Combined grades										
Males (n = 64)	3.30	1.48	16.19	9.93	29.33	8.93	28.94	11.15	13.23	4.17
Females (n = 70)	3.81	1.29	18.39	10.12	30.50	10.72	29.27	12.84	13.50	4.62
Total (n = 134)	3.57	1.40	17.34	10.05	29.94	9.88	29.11	12.02	13.37	4.40
Second year										
First grade										
Males (n = 21)	3.10	1.41	15.95	8.44	28.57	8.67	27.05	11.58	12.52	4.17
Females (n = 20)	3.45	1.19	16.65	9.23	34.65	10.39	32.70	17.00	12.45	3.72
Total (n = 41)	3.27	1.30	16.29	8.73	31.54	9.92	29.80	14.58	12.49	3.91
Fourth grade										
Males (n = 22)	4.00	1.20	23.64	5.84	36.64	10.98	35.73	16.07	17.05	2.20
Females (n = 25)	4.16	1.11	22.24	7.52	33.66	11.78	33.40	14.45	14.64	3.29
Total (n = 47)	4.09	1.14	22.89	6.75	35.06	11.39	34.49	15.10	15.77	3.07
Seventh grade										
Males (n = 21)	4.43	1.08	24.57	5.08	41.14	9.08	37.43	12.98	17.29	2.37
Females (n = 25)	4.56	.82	25.08	5.60	41.48	8.30	35.60	10.08	18.00	1.50
Total (n = 46)	4.50	.94	24.85	5.32	41.33	8.57	36.43	11.40	17.67	1.96
Combined grades										
Males (n = 64)	3.84	1.34	21.42	7.56	35.47	10.83	33.44	14.24	15.64	3.71
Females (n = 70)	4.10	1.12	21.66	8.10	36.74	10.72	33.99	13.75	15.21	3.68
Total (n = 134)	3.98	1.23	21.55	7.82	36.13	10.75	33.72	13.94	15.42	3.69

Table 14

(cont)

Assessment year and grade	CI		CR		AMS		ASM		VOM	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Third year										
Second grade										
Males (n = 21)	3.86	1.01	19.81	7.65	31.52	9.27	28.71	10.15	15.33	2.87
Females (n = 20)	3.95	1.15	17.75	9.72	32.05	9.21	31.65	15.51	13.70	3.23
Total (n = 41)	3.90	1.07	18.81	8.67	31.78	9.13	30.15	12.96	14.54	3.12
Fifth grade										
Males (n = 22)	4.64	.79	25.68	3.82	37.91	10.90	34.23	13.42	17.91	1.69
Females (n = 25)	4.12	1.20	23.04	6.45	32.96	10.16	30.36	13.15	16.28	4.03
Total (n = 47)	4.36	1.05	24.28	5.49	35.28	10.69	32.17	13.28	17.04	3.23
Eighth grade										
Males (n = 21)	4.24	.94	24.91	6.77	46.05	9.94	46.19	16.15	17.62	1.75
Females (n = 25)	4.92	.28	26.52	2.86	46.36	8.31	45.48	11.15	18.52	1.87
Total (n = 46)	4.61	.74	25.78	5.04	46.22	8.99	45.80	13.50	18.11	1.85
Combined grades										
Males (n = 64)	4.25	.96	23.50	6.70	38.48	11.56	36.34	15.13	16.97	2.42
Females (n = 70)	4.36	1.04	22.77	7.47	37.49	11.30	36.13	14.80	16.34	3.87
Total (n = 134)	4.31	1.00	23.12	7.09	37.96	11.39	36.23	14.90	16.64	3.14
Fourth year										
Third grade										
Males (n = 21)	4.19	1.21	23.10	6.40	32.9[illegible]	7.38	32.43	10.06	16.57	2.14
Females (n = 20)	4.45	.83	20.45	8.91	36.30	9.59	31.60	9.06	16.75	2.94
Total (n = 41)	4.3[illegible]	[illegible]4	21.81	7.74	34.56	8.59	32.02	9.48	16.66	2.53
Sixth grade										
Males (n = 22)	4.68	.72	26.59	2.13	41.91	11.19	42.32	12.52	18.64	1.09
Females (n = 25)	4.24	1.09	24.48	5.55	36.48	10.18	35.68	13.59	17.96	2.26
Total (n = 47)	4.45	.95	25.47	4.39	39.02	10.90	38.79	13.39	18.28	1.83
Ninth grade										
Males (n = 21)	4.62	.74	27.57	1.54	40.14	7.29	48.81	13.97	18.76	1.14
Females (n = 25)	4.88	.33	28.00	.00	43.80	8.44	51.00	11.25	19.24	1.09
Total (n = 46)	4.76	.57	27.80	1.05	42.13	8.06	50.00	12.47	19.02	1.13
Combined grades										
Males (n = 64)	4.50	.93	25.77	4.35	38.37	9.55	41.20	13.85	18.00	1.81
Females (n = 70)	4.53	.85	24.59	6.46	39.04	9.94	39.99	13.21	18.07	2.36
Total (n = 134)	4.52	.88	25.15	5.57	38.72	9.73	40.57	14.00	18.04	2.11

Table 15

Means and Standard Deviations for the Some-all, Dichotomous Sorting, Cardinality, and Arithmetic Addition Tasks for Subjects Assessed in all Four Years

Assessment year and grade	Some-all		Dichotomies		Cardinality		Arithmetic addition	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First year								
Kindergarten								
Males (n = 21)	3.52	.60	1.14	.73	1.67	1.24	4.67	5.69
Females (n = 20)	3.75	.64	.90	.97	1.80	1.24	6.85	5.52
Total (n = 41)	3.63	.62	1.02	.85	1.72	1.23	5.73	5.64
Third grade								
Males (n = 22)	3.77	.53	2.00	.76	4.00	.82	15.77	.53
Females (n = 25)	3.88	.34	2.04	.79	3.56	1.12	15.48	.96
Total (n = 47)	3.83	.48	2.02	.77	3.77	1.00	15.62	.80
Combined grades								
Males (n = 43)	3.65	.57	1.58	.85	2.86	1.57	10.35	6.86
Females (n = 45)	3.82	.53	1.53	1.04	2.78	1.46	11.64	5.70
Total (n = 88)	3.74	.56	1.56	.95	2.82	1.51	11.01	6.29
Second year								
First grade								
Males (n = 21)	3.62	.59	1.71	.90	3.10	1.09	13.67	3.58
Females (n = 20)	3.70	.66	1.80	1.11	2.95	1.54	13.85	3.38
Total (n = 41)	3.66	.62	1.76	.99	3.02	1.31	13.76	3.44
Fourth grade								
Males (n = 22)	3.86	.35	2.73	.55	4.18	.96	15.68	1.29
Females (n = 25)	3.92	.28	2.72	.54	3.64	.86	15.80	.65
Total (n = 47)	3.89	.31	2.72	.54	3.89	.94	15.75	.99
Combined grades								
Males (n = 43)	3.74	.49	2.23	.90	3.65	1.15	14.70	2.82
Females (n = 45)	3.82	.49	2.31	.95	3.33	1.24	14.93	2.47
Total (n = 88)	3.78	.49	2.27	.92	3.49	1.20	14.82	2.64

Table 15

(cont)

Assessment year and grade	Sum-all		Dichotomies		Cardinality		Arithmetic addition	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Third year								
Second grade								
Males (n = 21)	3.81	.40	2.38	.92	3.62	1.07	15.10	2.19
Females (n = 20)	3.95	.22	2.05	.89	3.95	.94	15.15	2.01
Total (n = 41)	3.88	.33	2.22	.91	3.78	1.01	15.12	2.08
Fifth grade								
Males (n = 22)	3.96	.21	2.91	.29	4.41	.80	15.77	.69
Females (n = 25)	4.00	.00	2.76	.52	4.12	.83	16.00	.00
Total (n = 47)	3.98	.15	2.82	.43	4.26	.82	15.89	.48
Combined grades								
Males (n = 43)	3.88	.32	2.65	.72	4.02	1.01	15.44	1.62
Females (n = 45)	3.98	.15	2.44	.79	4.04	.88	15.62	1.39
Total (n = 88)	3.93	.25	2.55	.76	4.03	.94	15.53	1.50
Fourth year								
Third grade								
Males (n = 21)	3.76	.54	2.71	.72	4.33	.91	15.86	.48
Females (n = 20)	3.85	.49	2.55	.60	3.85	1.09	15.80	.41
Total (n = 41)	3.81	.51	2.63	.66	4.10	1.02	15.83	.44
Sixth grade								
Males (n = 22)	3.91	.29	2.77	.53	4.32	.84	15.46	1.53
Females (n = 25)	3.96	.20	2.80	.50	3.84	.99	15.92	.28
Total (n = 47)	3.94	.25	2.79	.51	4.06	.94	15.70	1.08
Combined grades								
Males (n = 43)	3.84	.43	2.74	.62	4.33	.87	15.65	1.15
Females (n = 45)	3.91	.36	2.69	.56	3.84	1.02	15.87	.34
Total (n = 88)	3.88	.40	2.72	.59	4.08	.97	15.76	.84

Table 16

Means and Standard Deviations for the Seriation, Length Transitivity, and Weight Transitivity Tasks for Subjects Assessed in All Four Years

Assessment year and grade	Seriation		Length transitivity		Weight transitivity	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First year						
Kindergarten						
Males (n = 21)	1.71	1.06	3.57	2.01	4.38	1.07
Females (n = 20)	1.95	1.00	3.90	1.83	4.50	1.32
Total (n = 41)	1.83	1.02	3.73	1.91	4.44	1.18
Third grade						
Males (n = 22)	3.73	.83	4.50	1.47	4.77	1.07
Females (n = 25)	3.60	.65	4.40	1.44	4.92	.40
Total (n = 47)	3.66	.73	4.45	1.44	4.85	.78
Combined grades						
Males (n = 43)	2.74	1.38	4.05	1.80	4.58	1.07
Females (n = 45)	2.87	1.16	4.18	1.63	4.73	.94
Total (n = 88)	2.81	1.27	4.11	1.70	4.66	1.00
Second year						
First grade						
Males (n = 21)	3.10	.83	3.71	2.15	4.86	.65
Females (n = 20)	2.90	1.25	3.80	2.02	4.40	1.57
Total (n = 41)	3.00	1.05	3.76	2.06	4.63	1.20
Fourth grade						
Males (n = 22)	4.41	.57	5.00	.00	5.00	.00
Females (n = 25)	3.92	.76	4.84	.55	4.92	.40
Total (n = 47)	4.15	.75	4.92	.41	4.96	.29
Combined grades						
Males (n = 43)	3.77	1.00	4.37	1.62	4.93	.46
Females (n = 45)	3.47	1.12	4.38	1.48	4.69	1.10
Total (n = 88)	3.61	1.07	4.38	1.54	4.81	.86

Table 16

(cont)

Assessment year and grade	Seriation		Length transitivity		Weight transitivity	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Third year						
Second grade						
Males (n = 21)	3.48	.93	3.95	2.01	4.76	1.09
Females (n = 20)	3.70	1.03	4.25	1.83	4.30	1.72
Total (n = 41)	3.59	.97	4.10	1.91	4.54	1.43
Fifth grade						
Males (n = 22)	4.14	.77	4.77	1.07	5.00	.00
Females (n = 25)	4.16	.80	4.76	.66	4.60	1.38
Total (n = 47)	4.15	.78	4.77	.87	4.79	1.02
Combined grades						
Males (n = 43)	3.81	.91	4.37	1.63	4.88	.76
Females (n = 45)	3.96	.93	4.53	1.32	4.47	1.53
Total (n = 88)	3.89	.92	4.46	1.48	4.67	1.23
Fourth year						
Third grade						
Males (n = 21)	4.00	.84	4.76	.77	4.76	1.09
Females (n = 20)	4.20	.83	4.50	1.40	4.65	1.18
Total (n = 41)	4.10	.83	4.63	1.11	4.71	1.12
Sixth grade						
Males (n = 22)	4.64	.49	5.00	.00	5.00	.00
Females (n = 25)	3.96	.79	4.56	1.39	4.72	1.06
Total (n = 47)	4.28	.74	4.77	1.03	4.85	.78
Combined grades						
Males (n = 43)	4.33	.73	4.88	.54	4.88	.76
Females (n = 45)	4.07	.81	4.53	1.38	4.69	1.10
Total (n = 88)	4.19	.79	4.74	1.06	4.78	.95

Table 17

Means and Standard Deviations for the Number Conservation, Length Conservation, and Weight Conservation Tasks for Subjects Assessed in All Four Years

Assessment year and grade	Number conservation		Length conservation				Weight conservation			
			Identity		Equivalence		Identity		Equivalence	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First year										
Kindergarten										
Males (n = 21)	3.91	2.14	3.05	1.86	1.81	2.02	3.19	1.66	1.33	1.93
Females (n = 20)	3.95	2.39	3.70	1.63	2.50	2.33	3.90	2.08	2.50	2.40
Total (n = 41)	3.93	2.24	3.37	1.76	2.15	2.17	3.54	1.89	1.90	2.22
Third grade										
Males (n = 22)	6.82	.50	5.32	1.43	5.27	1.91	5.32	1.55	5.05	2.15
Females (n = 25)	6.52	1.12	4.60	1.80	3.64	2.83	4.60	1.83	4.08	2.66
Total (n = 47)	6.66	.89	4.94	1.66	4.40	2.55	4.94	1.72	4.53	2.46
Combined grades										
Males (n = 43)	5.40	2.12	4.21	1.99	3.58	2.61	4.28	1.92	3.23	2.76
Females (n = 45)	5.38	2.20	4.20	1.77	3.13	2.65	4.29	1.95	3.38	2.64
Total (n = 88)	5.39	2.15	4.21	1.87	3.35	2.63	4.28	1.92	3.31	2.68
Second year										
First grade										
Males (n = 21)	5.71	2.03	4.19	1.94	4.00	2.49	4.33	1.96	3.19	2.70
Females (n = 20)	5.30	2.27	4.55	1.73	3.85	2.52	4.40	1.82	4.10	2.47
Total (n = 41)	5.51	2.13	4.37	1.83	3.93	2.47	4.37	1.87	3.63	2.60
Fourth grade										
Males (n = 22)	6.86	.35	5.50	1.22	5.32	1.84	5.73	.94	5.55	1.50
Females (n = 25)	6.76	.52	5.00	1.68	4.36	2.55	5.16	1.63	4.44	2.52
Total (n = 47)	6.81	.45	5.23	1.49	4.81	2.27	5.43	1.36	4.96	2.16
Combined grades										
Males (n = 43)	6.30	1.54	4.86	1.73	4.67	2.25	5.05	1.66	4.40	2.45
Females (n = 45)	6.11	1.71	4.80	1.70	4.13	2.52	4.82	1.74	4.29	2.47
Total (n = 88)	6.21	1.62	4.83	1.70	4.40	2.40	4.93	1.69	4.34	2.45

Table 17

(cont)

Assessment year and grade	Number conservation		Length conservation				Weight conservation			
			Identity		Equivalence		Identity		Equivalence	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Third year										
Second grade										
Males (n = 21)	6.86	.65	5.19	1.54	5.14	1.88	5.00	1.67	4.81	2.11
Females (n = 20)	6.20	2.02	4.65	1.63	4.80	1.79	4.25	2.00	3.80	2.59
Total (n = 41)	6.54	1.50	4.93	1.59	4.98	1.82	4.63	1.85	4.32	2.38
Fifth grade										
Males (n = 22)	7.00	.00	5.64	1.18	5.64	1.18	5.82	.85	5.68	1.13
Females (n = 25)	7.00	.00	5.92	.40	5.56	1.08	5.16	1.57	5.04	2.01
Total (n = 47)	7.00	.00	5.79	.86	5.60	1.12	5.47	1.32	5.34	1.67
Combined grades										
Males (n = 43)	6.93	.46	5.42	1.37	5.40	1.56	5.42	1.37	5.26	1.72
Females (n = 45)	6.64	1.38	5.36	1.28	5.22	1.48	4.76	1.81	4.49	2.34
Total (n = 88)	6.78	1.04	5.39	1.32	5.31	1.51	5.08	1.63	4.86	2.09
Fourth year										
Third grade										
Males (n = 21)	6.34	2.11	5.81	.60	5.71	1.31	5.57	1.21	4.91	2.12
Females (n = 20)	6.60	1.39	5.00	1.65	5.10	1.74	4.95	1.82	4.65	2.06
Total (n = 41)	6.46	1.78	5.42	1.28	5.42	1.55	5.27	1.55	4.78	2.07
Sixth grade										
Males (n = 22)	7.00	.00	5.82	.85	5.73	1.28	6.00	.00	6.00	.00
Females (n = 25)	7.00	.00	5.72	.98	5.72	.84	5.48	1.33	5.44	1.33
Total (n = 47)	7.00	.00	5.77	.91	5.72	1.06	5.72	.99	5.70	1.00
Combined grades										
Males (n = 43)	6.67	1.49	5.81	.73	5.72	1.28	5.79	.86	5.47	1.56
Females (n = 45)	6.82	.94	5.40	1.36	5.44	1.34	5.24	1.57	5.09	1.72
Total (n = 88)	6.75	1.23	5.60	1.11	5.58	1.31	5.51	1.30	5.27	1.65

Table 18

Analysis of Variance Summary for the *Groupement* Tasks with Two Between Subject Factors (Sex and Grade Group) and One Within Subject Factor (Assessment Year)

	Sources of variance[a]														
	Sex		Grade		Sex x Grade			Year		Year x Sex		Year x Grade		Year x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error between	MS	F value	MS	F value	MS	F value	MS	F value	Error within
Groupement I	7.44	1.70	110.58	25.33[c]	7.31	1.67	4.36	48.49	32.99[c]	1.30	.89	4.27	2.91[c]	.99	.68	1.47
Groupement II	3.67	.73	109.04	21.78[c]	5.64	1.13	5.01	41.06	26.84[c]	.50	.33	4.33	2.83[b]	1.19	.78	1.53
Groupement III	25.69	2.70	109.38	11.49[c]	6.00	.63	9.52	42.86	13.11[c]	.41	.13	1.31	.40	3.81	1.17	3.27
Groupement IV	.07	.01	180.97	23.17[c]	.88	.11	8.16	112.61	45.04[c]	3.25	1.30	8.05	3.22[c]	2.50	1.00	2.50
Groupements I-IV composition	50.55	1.13	993.53	22.27[c]	51.55	1.16	44.61	453.35	42.53[c]	5.03	.47	39.55	3.71[c]	1.84	.17	10.66
Groupements I-IV inversion	8.26	.93	199.03	22.40[c]	6.27	.71	8.89	85.98	29.85[c]	.85	.30	10.48	3.64[c]	4.44	1.54	2.88
Groupements I-IV combined	99.69	1.34	1982.42	26.59[c]	66.75	.90	74.56	914.85	62.92[c]	9.12	.63	38.29	2.63[b]	5.32	.37	14.54
Groupement V	1.79	.97	15.51	8.37[c]	.19	.10	1.85	13.17	12.04[c]	.15	.14	1.33	1.21	2.82	2.56[b]	1.10
Groupement VI	2.77	1.23	26.14	11.58[c]	1.09	.48	2.26	11.64	12.25[c]	.59	.62	5.31	5.59[c]	.28	.29	.95
Groupement VII	.02	.01	29.73	6.94[c]	.93	.22	4.28	53.16	29.05[c]	.22	.12	2.88	1.57	1.87	1.02	1.83
Groupement VIII	5.54	1.49	68.77	18.46[c]	1.92	.51	3.73	36.28	23.71[c]	.73	.48	3.39	2.22[b]	1.68	1.10	1.53
Groupements V-VIII composition	16.98	1.84	195.81	21.22[c]	6.51	.71	9.23	138.07	51.33[c]	.38	.14	10.61	3.94[c]	1.67	.62	2.69
Groupements V-VIII reciprocity	1.17	.17	76.63	11.31[c]	.62	.09	6.77	67.66	36.77[c]	.40	.22	6.94	3.77[c]	3.77	2.05	1.84
Groupements V-VIII combined	27.08	.93	514.61	17.58[c]	11.12	.38	29.27	395.21	59.07[c]	1.57	.23	33.72	5.04[c]	8.28	1.24	6.69

[a] Degrees of freedom: Sex = 1, Grade = 2, Sex x Grade = 2, Error between = 128, Year = 3, Year x Sex = 3, Year x Grade = 6, Year x Sex x Grade = 6, Error within = 384.

[b] $p < .05$

[c] $p < .01$

Table 19

Analysis of Variance for Class Inclusion, Combinatorial Reasoning, Auditory Memory Span, Auditory Sequential Memory, and Visual Orientation Memory with Two Between Subject Factors (Sex and Grade Group) and One Within Subject Factor (Assessment Year)

	Sources of variance[a]														
	Sex		Grade		Sex x Grade			Year		Year x Sex		Year x Grade		Year x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error between	MS	F value	MS	F value	MS	F value	MS	F value	Error within
Class inclusion	6.91	3.33	43.98	21.18[c]	5.28	2.54	2.08	22.92	29.96[c]	1.55	2.01	3.41	4.43[c]	1.27	1.66	.77
Combinatorial reasoning	2.30	.03	4040.17	54.33[c]	61.42	.83	74.37	1471.84	43.74[c]	75.13	2.23	235.79	7.01[c]	15.84	.47	33.65
Auditory memory span	37.39	.15	4865.19	19.64[c]	493.46	1.99	247.73	2127.30	57.08[c]	37.02	.99	165.69	4.45[c]	55.04	1.48	37.27
Auditory sequential memory	2.53	.01	7669.30	17.80[c]	464.67	1.08	430.78	3071.90	44.88[c]	20.78	.30	419.13	6.12[c]	61.87	.90	68.44
Visual orientation memory	4.28	.29	1053.95	70.85[c]	45.28	3.04	14.88	524.01	121.58[c]	5.81	1.35	76.93	17.86[c]	6.90	1.60	4.31

[a]Degrees of freedom: Sex = 1, Grade = 2, Sex x Grade = 2, Error between = 128, Year = 3, Year x Sex = 3, Year x Grade = 6, Year x Sex x Grade = 6, Error within = 384.

[b]$p < .05$.

[c]$p < .01$.

Table 20

Analysis of Variance Summary for the Some-All, Dichotomous Sorting, Cardinality, and Arithmetic Addition Tasks with Two Between Subject Factors (Sex and Grade Group) and One Within Subject Factor (Assessment Year)

	Sources of variance[a]														
	Sex		Grade		Sex x Grade			Year		Year x Sex		Year x Grade		Year x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error between	MS	F value	MS	F value	MS	F value	MS	F value	Error within
Some-all	.96	3.73	2.28	8.89[c]	.10	.41	.26	.67	4.04[c]	.05	.29	.08	.48	.01	.07	.17
Dichotomies	.29	.29	41.11	41.12[c]	.43	.43	1.00	22.98	62.11[c]	.30	.81	3.37	9.11[c]	.14	.38	.37
Cardinality	4.07	1.91	62.76	29.52[c]	3.43	1.61	2.13	30.56	43.04[c]	1.13	1.60	16.80	23.66[c]	.44	.62	.71
Arithmetic addition	20.42	2.02	847.93	83.76[c]	4.65	.46	10.12	432.40	93.80[c]	6.48	1.41	456.80	99.09[c]	10.17	2.21	4.61

[a]Degrees of freedom: Sex = 1, Grade = 1, Sex x Grade = 1, Error between = 84, Year = 3, Year x Sex = 3, Year x Grade = 3, Year x Sex x Grade = 3, Error within = 252.

[b]$p < .05$.

[c]$p < .01$.

Table 21

Analysis of Variance Summary for the Seriation and Transitivity Tasks with Two Between Subject Factors (Sex and Grade Group) and One Within Subject Factor (Assessment Year)

	Sources of variance[a]														
	Sex		Grade		Sex x Grade			Year		Year x Sex		Year x Grade		Year x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error between	MS	F value	MS	F value	MS	F value	MS	F value	Error within
Seriation	.48	.35	76.51	55.94[c]	4.10	3.00	1.37	31.11	59.83[c]	1.25	2.40	11.27	21.67[c]	.50	.97	.52
Transitivity of length	.02	.01	39.29	16.43[c]	1.85	.77	2.39	5.21	2.68[b]	1.21	.62	3.76	1.93	.06	.03	1.95
Transitivity of weight	2.70	2.63	7.39	7.18[c]	.12	.12	1.03	.51	.50	1.25	1.21	.25	.25	.28	.27	1.03

[a]Degrees of freedom: Sex = 1, Grade = 1, Sex x Grade = 1, Error between = 84, Year = 3, Year x Sex = 3, Year x Grade = 3, Year x Sex x Grade = 3, Error within = 252.

[b]$p < .05$.

[c]$p < .01$.

Table 22

Analysis of Variance Summary for the Conservation Tasks with Two Between Subject Factors (Sex and Grade Group) and One Within Subject Factor (Assessment Year)

	Sources of variance[a]														
	Sex		Grade		Sex x Grade			Year		Year x Sex		Year x Grade		Year x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error between	MS	F value	MS	F value	MS	F value	MS	F value	Error within
Conservation of number	.66	.20	139.57	43.10[c]	.18	.05	3.24	37.53	25.88[c]	.81	.56	24.29	16.75[c]	1.25	.86	1.45
Identity conservation of length	1.64	.40	74.05	18.21[c]	.68	.16	4.07	34.43	24.25[c]	.77	.54	5.35	3.77[b]	6.70	4.72[c]	1.42
Equivalence conservation of length	11.38	1.61	93.65	13.26[c]	6.96	.99	7.06	89.26	33.94[c]	.60	.23	16.36	6.22[c]	9.50	3.61[b]	2.63
Identity conservation of weight	11.14	2.15	79.67	15.39[c]	4.77	.92	5.18	22.75	14.49[c]	2.06	1.31	3.26	2.08	2.89	1.84	1.57
Equivalence conservation of weight	6.70	.82	193.96	23.79[c]	22.78	2.79	8.15	63.56	20.57[c]	3.35	1.08	13.18	4.27[c]	8.49	2.75[b]	3.09

[a] Degrees of freedom: Sex = 1, Grade = 1, Sex x Grade = 1, Error between = 84, Year = 3, Year x Sex = 3, Year x Grade = 3, Year x Sex x Grade = 3, Error within = 252.

[b] $p < .05$.

[c] $p < .01$.

Table 23

Trend Analyses Summary for the *Groupement* Tasks for the Four Assessment Years (N = 134)

	Sources of variance and trend components[a]														
	Sex		Grade		Sex x Grade			Linear		Linear x Sex		Linear x Grade		Linear x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Groupement I	29.75	1.70	442.31	25.33[c]	29.24	1.68	17.46	2850.18	79.25[c]	47.47	1.32	145.04	4.03[b]	41.39	1.15	35.96
Groupement II	14.69	.73	436.16	21.78[c]	22.55	1.13	20.03	2184.19	55.60[c]	26.69	.62	221.76	5.65[c]	12.30	.31	39.28
Groupement III	102.75	2.70	437.54	11.49[c]	24.02	.63	38.07	2545.19	34.17[c]	1.05	.01	17.47	.23	40.96	.55	74.49
Groupement IV	.30	.009	755.87	23.17[c]	3.51	.11	32.63	6735.07	103.52[c]	91.37	1.40	351.11	5.40[c]	66.94	1.03	65.06
Groupement V	7.17	.97	62.04	8.37[c]	.78	.10	7.41	627.61	19.90[c]	2.16	.07	58.18	1.84	60.12	1.91	31.54
Groupement VI	11.07	1.23	104.55	11.58[c]	4.36	.48	9.03	658.28	32.34[c]	8.49	.42	279.02	13.71[c]	1.24	.06	20.36
Groupement VII	.09	.005	118.90	6.94[c]	3.72	.22	17.13	2686.57	55.11[c]	10.31	.21	82.72	1.70	12.15	.25	48.75
Groupement VIII	22.17	1.49	275.07	18.46[c]	7.67	.51	14.90	1762.66	50.27[c]	23.25	.66	145.34	4.15[c]	34.59	.99	35.06
Class composition	202.22	1.13	3974.14	22.27[c]	206.19	1.16	178.44	26488.48	94.00[c]	187.52	.67	1981.53	7.06[c]	62.64	.22	281.76
Class negation	33.05	.93	796.12	22.40[c]	25.10	.71	35.54	4884.19	69.06[c]	44.59	.63	550.79	7.79[c]	68.67	.97	70.73
Combined classes	398.76	1.34	7929.67	26.59[c]	266.98	.90	298.23	54121.26	141.90[c]	415.00	1.09	1762.85	4.62[c]	207.89	.55	381.42
Relations composition	67.93	1.84	783.24	21.22[c]	26.04	.71	36.91	7021.64	101.04[c]	.09	.001	576.54	8.30[c]	24.06	.35	69.49
Relations reciprocity	4.69	.17	306.50	11.31[c]	2.47	.09	27.10	3688.13	75.16[c]	.02	.0004	373.08	7.60[c]	11.96	.24	49.07
Combined relations	108.32	.93	2058.46	17.58[c]	44.49	.38	117.08	20887.53	117.12[c]	.03	.0002	1827.82	10.25[c]	47.57	.27	178.35

Table 23

(cont)

Variable	Sources of variance and trend components[a]																
	Quadratic		Quadratic x Sex		Quadratic x Grade		Quadratic x Sex x Grade			Cubic		Cubic x Sex		Cubic x Grade		Cubic x Sex x Grade	
	MS	F value	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Groupement I	.75	.14	6.05	1.12	7.47	1.39	3.62	.67	5.38	55.19	2.21	.46	.02	73.68	2.94	.08	.003	25.03
Groupement II	9.14	1.56	.98	.17	3.82	.65	10.55	1.80	5.86	233.80	9.97[c]	.92	.04	18.80	.80	6.15	.26	23.44
Groupement III	.27	.02	.45	.03	2.26	.17	32.03	2.42	13.26	25.10	.45	21.33	.38	49.75	.89	27.45	.49	55.63
Groupement IV	4.30	.43	3.98	.40	25.47	2.57	11.32	1.14	9.91	.00	.00	84.02	2.39	4.46	.13	27.89	.79	35.17
Groupement V	32.51	10.58[c]	.90	.29	1.17	.38	17.42	5.67[c]	3.07	.00	.00	2.42	.13	16.01	.85	21.83	1.17	18.73
Groupement VI	.90	.29	4.49	1.45	6.55	2.11	.62	.20	3.10	35.53	1.70	4.34	.21	6.86	.33	12.26	.59	20.93
Groupement VII	100.43	14.48[c]	.01	.001	14.54	2.10	14.53	2.10	6.93	.75	.03	2.54	.10	17.22	.65	27.39	1.03	26.57
Groupement VIII	80.72	13.46[c]	1.20	.20	.22	.04	5.96	.99	6.00	10.78	.41	14.28	.54	56.93	2.15	36.37	1.37	26.52
Class composition	43.10	1.09	22.29	.56	35.20	.89	6.14	.15	39.66	496.75	3.11	3.86	.02	208.62	1.31	17.15	.11	159.57
Class negation	48.96	4.74[c]	.003	.0003	15.43	1.49	29.55	2.86	10.33	29.62	.59	6.65	.13	.88	.02	49.71	.98	50.56
Combined classes	.19	.004	22.80	.44	66.22	1.27	14.60	.28	52.08	768.96	3.33	18.23	.08	203.20	.88	38.47	.17	230.78
Relations composition	247.19	26.73[c]	4.36	.47	3.02	.33	6.36	.69	9.25	26.87	.59	1.20	.03	45.23	.99	44.22	.97	45.74
Relations reciprocity	64.54	9.14[c]	4.74	.67	4.40	.62	42.33	5.99[c]	7.06	48.96	1.90	.41	.02	21.01	.82	2.64	.10	25.74
Combined relations	564.37	24.31[c]	18.18	.78	14.27	.61	76.29	3.29[b]	23.21	3.29	.03	3.01	.03	124.11	1.16	67.52	.63	107.14

[a]Degrees of freedom: Sex = 1, Grade = 2, Sex x Grade = 1, Error = 128, Linear = 1, Linear x Sex = 1, Linear x Grade = 2, Linear x Sex x Grade = 2, Quadratic = 1, Quadratic x Sex = 1, Quadratic x Grade = 2, Quadratic x Sex x Grade = 2, Cubic = 1, Cubic x Sex = 1, Cubic x Grade = 2, Cubic x Sex x Grade = 2, Error = 128.

[b]$p < .05$.

[c]$p < .01$.

Table 24

Trend Analyses Summary for Class Inclusion, Combinatorial Reasoning, Auditory Memory Span, Auditory Sequential Memory, and Visual Orientation Memory for the Four Assessment Years (N = 134)

	Sources of variance and trend components[a]															
	Sex		Grade		Sex x Grade			Linear		Linear x Sex		Linear x Grade		Linear x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Class inclusion	27.65	3.33	175.92	21.18[c]	21.14	2.54	8.31	1347.95	84.19[c]	87.27	5.45[b]	199.75	12.48[c]	27.40	1.71	16.01
Combinatorial reasoning	9.21	.03	16160.68	54.33[c]	245.68	.83	297.48	83850.02	125.84[c]	4117.93	6.18[b]	11410.58	17.12[c]	624.43	.94	666.33
Auditory memory span	149.58	.15	19460.77	19.64[c]	1973.83	1.99	990.90	106404.29	197.56[c]	478.92	.89	226.53	.42	1568.10	2.91	538.59
Auditory sequential memory	10.13	.01	30677.19	17.80[c]	1858.70	1.08	1723.12	182190.15	148.12[c]	981.20	.80	10644.09	8.65[c]	978.56	.80	1230.05
Visual orientation memory	17.10	.29	4215.79	70.85[c]	181.12	3.04	59.50	31026.27	357.93[c]	20.45	.24	4321.44	49.85[c]	17.97	.21	86.68

Table 24 (Cont.)

Variable	Sources of variance and trend components[a]																
	Quadratic		Quadratic x Sex		Quadratic x Grade		Quadratic x Sex x Grade			Cubic		Cubic x Sex		Cubic x Grade		Cubic x Sex x Grade		
	MS	F value	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Class inclusion	5.44	1.66	1.11	.34	.66	.20	3.57	1.09	3.28	.19	.01	.06	.01	1.41	.10	31.18	2.31	13.48
Combinatorial reasoning	636.30	4.93[b]	76.39	.59	479.12	3.71[b]	30.85	.24	11.36	1279.07	1.81	7.92	.01	341.37	.48	171.90	.24	706.86
Auditory memory span	3955.10	24.36[c]	81.81	.50	1154.34	7.11[c]	130.72	.81	162.38	1457.94	1.65	1332.97	1.51	3943.38	4.45[b]	1080.86	1.22	885.69
Auditory sequential memory	10.22	.03	49.48	.14	634.73	1.85	514.66	1.50	342.63	2072.60	1.78	18.25	.02	11329.97	9.74[c]	160.17	.14	1163.09
Visual orientation memory	56.49	3.25	64.53	3.71	55.12	3.17[b]	36.33	2.09	17.38	132.01	1.56	5.47	.06	18.46	.22	214.09	2.52	84.89

[a] Degrees of freedom: Sex = 1, Grade = 2, Sex x Grade = 1, Error = 128, Linear = 1, Linear x Sex = 1, Linear x Grade = 2, Linear x Sex x Grade = 2, Quadratic = 1, Quadratic x Sex = 1, Quadratic x Grade = 2, Quadratic x Sex x Grade = 2, Cubic = 1, Cubic x Sex = 1, Cubic x Grade = 2, Cubic x Sex x Grade = 2, Error = 128.

[b] $p < .05$.

[c] $p < .01$.

Table 25

Trend Analyses Summary for the Number Conservation, Length Conservation, and Weight Conservation Tasks for the Four Assessment Years (N=88)

	Sources of variance and trend components[a]														
	Sex		Grade		Sex x Grade			Linear		Linear x Sex		Linear x Grade		Linear x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Conservation of number	2.64	.20	558.28	43.10[c]	.70	.05	12.95	1919.56	42.40[c]	3.55	.08	1214.18	26.85[c]	1.82	.04	45.21
Identity conservation of length	6.57	.40	296.21	18.21[c]	2.64	.16	16.27	1985.50	57.03[c]	32.54	.93	286.10	8.22[c]	343.44	9.86[c]	34.81
Equivalence conservation of length	45.52	1.61	374.59	13.26[c]	27.85	.99	28.24	5070.73	85.68[c]	17.13	.29	829.27	14.01[c]	531.61	8.98[c]	59.18
Identity conservation of weight	44.57	2.15	318.67	15.39[c]	19.07	.92	20.71	1290.56	36.80[c]	97.62	2.78	193.04	5.51[b]	154.20	4.40[b]	35.07
Equivalence conservation of weight	26.82	.82	775.82	23.79[c]	91.13	2.79	32.61	3627.56	55.12[c]	108.84	1.65	622.20	9.45[c]	337.74	5.13[b]	65.82

Table 25 (Cont.)

	Sources of variance and trend components[a]																
	Quadratic		Quadratic x Sex		Quadratic x Grade		Quadratic x Sex x Grade			Cubic		Cubic x Sex		Cubic x Grade		Cubic x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Conservation of number	63.92	17.71[c]	8.11	2.25	48.24	13.37[c]	13.60	3.77	3.61	12.38	.52	4.43	.19	1.75	.07	5.06	.21	23.68
Identity conservation of length	14.73	3.47	1.98	.47	.93	.22	2.13	.50	4.24	6.55	.22	3.46	.12	30.45	1.04	48.15	1.64	29.28
Equivalence conservation of length	52.55	4.76[b]	.01	.01	24.90	2.26	7.54	.68	11.04	22.00	.51	19.11	.44	27.69	.64	.47	.01	43.46
Identity conservation of weight	4.10	.78	2.71	.51	.06	.01	3.36	.64	5.27	54.10	1.66	12.71	.39	1.99	.06	2.29	.07	32.59
Equivalence conservation of weight	34.38	3.06	9.07	.81	30.35	2.70	3.41	.30	11.24	13.92	.22	46.87	.74	16.70	.26	154.66	2.44	63.49

[a]Degrees of freedom: Sex = 1, Grade = 1, Sex x Grade = 1, Error = 84, Linear = 1, Linear x Sex = 1, Linear x Grade = 1, Linear x Sex x Grade = 1, Quadratic = 1, Quadratic x Sex = 1, Quadratic x Grade = 1, Quadratic x Sex x Grade = 1, Cubic = 1, Cubic x Sex = 1, Cubic x Grade = 1, Cubic x Sex x Grade = 1, Error = 84.

[b]$p < .05$.

[c]$p < .01$.

Table 26

Trend Analyses Summary for the Some-all, Dichotomous Sorting, Cardinality, and Arithmetic Addition Tasks for the Four Assessment Years (N = 88)

	Sources of variance and trend components														
	Sex		Grade		Sex x Grade			Linear		Linear x Sex		Linear x Grade		Linear x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Some-all	3.82	3.73	9.11	8.86[b]	.42	.41	1.02	27.20	7.08[c]	1.67	.43	2.18	.57	.17	.04	3.85
Dichotomies	1.18	.29	164.45	41.12[c]	1.73	.43	4.00	1237.50	153.07[c]	2.07	.26	181.34	22.43[c]	.00	.00	8.08
Cardinality	16.28	1.91	251.03	29.52[c]	13.72	1.61	8.50	1649.56	103.99[c]	16.12	1.02	944.33	59.53[c]	12.49	.79	15.86
Arithmetic addition	81.66	2.02	3391.74	83.76[c]	18.62	.46	40.50	19710.10	135.47[c]	238.82	1.64	21232.98	145.94[c]	465.71	3.20	145.49

Table 26 (Cont.)

	Sources of variance and trend components																
	Quadratic		Quadratic x Sex		Quadratic x Grade		Quadratic x Sex x Grade			Cubic		Cubic x Sex		Cubic x Grade		Cubic x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Some-all	.92	1.43	.12	.18	.01	.01	.01	.01	.64	8.28	2.86	.46	.16	2.62	.90	.47	.16	2.89
Dichotomies	26.18	16.54[c]	.01	.01	4.03	2.55	.81	.51	1.58	10.23	1.63	15.83	2.52	.79	.13	4.58	.73	6.29
Cardinality	34.38	16.39[c]	1.57	.75	9.80	4.67[b]	1.10	.52	2.10	12.38	.77	44.06	2.73	14.84	.92	8.52	.53	16.13
Arithmetic addition	1127.56	58.60[c]	26.37	1.37	1059.65	55.07[c]	23.20	1.21	19.24	595.92	17.02[c]	18.38	.52	876.73	25.04[c]	28.54	.81	35.02

[a] Degrees of freedom: Sex = 1, Grade = 1, Sex x Grade = 1, Error = 84, Linear = 1, Linear x Sex = 1, Linear x Grade = 1, Linear x Sex x Grade = 1, Quadratic = 1, Quadratic x Sex = 1, Quadratic x Grade = 1, Quadratic x Sex x Grade = 1, Cubic = 1, Cubic x Sex = 1, Cubic x Grade = 1, Cubic x Sex x Grade = 1, Error = 84.

[b] $p < .05$.

[c] $p < .01$.

Table 27

Trend Analyses Summary for the Seriation, Length Transitivity, and Weight Transitivity Tasks for the Four Assessment Years (N = 88)

	Sources of variance and trend components[a]															
	Sex		Grade		Sex x Grade			Linear		Linear x Sex		Linear x Grade		Linear x Sex x Grade		
Variable	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Seriation	1.92	.35	306.05	55.93[c]	16.41	3.00	5.47	1728.41	159.61[c]	10.83	1.00	665.68	61.47[c]	11.43	1.06	10.83
Transitivity of length	.06	.01	157.16	16.43[c]	7.38	.77	9.57	301.92	7.99[c]	36.56	.97	104.59	2.77	2.58	.07	37.78
Transitivity of weight	10.81	2.63	29.56	7.18[c]	.49	.12	4.11	5.01	.25	32.51	1.65	14.89	.75	4.47	.23	19.76

Table 27 (Cont.)

Variable	Sources of variance and trend components[a]																
	Quadratic		Quadratic x Sex		Quadratic x Grade		Quadratic x Sex x Grade			Cubic		Cubic x Sex		Cubic x Grade		Cubic x Sex x Grade		
	MS	F value	MS	F value	MS	F value	MS	F value	Error	MS	F value	MS	F value	MS	F value	MS	F value	Error
Seriation	22.00	9.48[c]	.01	.01	1.92	.83	3.03	1.31	2.32	28.41	3.33	64.19	7.52[c]	.71	.08	3.45	.41	8.54
Transitivity of length	.01	.01	3.28	.44	20.36	2.71	.01	.01	7.52	10.92	.26	19.77	.48	18.97	.46	1.08	.03	41.43
Transitivity of weight	.10	.03	8.33	2.07	.05	.01	1.83	.45	4.03	25.10	1.14	.72	.03	.07	.01	3.07	.14	21.95

[a]Degrees of freedom: Sex = 1, Grade = 1, Sex x Grade = 1, Error = 84, Linear = 1, Linear x Sex = 1, Linear x Grade = 1, Linear x Sex x Grade = 1, Quadratic = 1, Quadratic x Sex = 1, Quadratic x Grade = 1, Quadratic x Sex x Grade = 1, Cubic = 1, Cubic x Sex = 1, Cubic x Grade = 1, Cubic x Sex x Grade = 1, Error = 84.

[b]$p < .05$.

[c]$p < .01$.

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Table 28

CORRELATIONS AMONG TWO PIAGETIAN TESTS AND THREE MEMORY TESTS FOR THE FOUR ANNUAL ASSESSMENTS

		Year one						Year two					Year three					Year four				
		Age	CR	CI	WM	DM	VM	CR	CI	WM	DM	VM	CR	CI	WM	DM	VM	CR	CI	WM	DM	VM
Year one	CR	.63																				
	CI	.47	.49																			
	WM	.41	.40	.36																		
	DM	.39	.36	.29	.70																	
	VM	.76	.64	.47	.39	.37																
Year two	CR	.43	.41	.35	.27	.21	.39															
	CI	.40	.38	.44	.24	.28	.39	.30														
	WM	.37	.23	.31	.55	.52	.34	.22	.30													
	DM	.20	.14	.19	.42	.50	.17	.33	.34	.64												
	VM	.57	.47	.38	.27	.31	.65	.43	.39	.30	.32											
Year three	CR	.39	.43	.31	.28	.17	.42	.39	.34	.02	.13	.24										
	CI	.29	.29	.32	.29	.16	.27	.32	.44	.24	.22	.40	.22									
	WM	.51	.34	.23	.67	.65	.43	.33	.36	.62	.56	.39	.30	.34								
	DM	.42	.32	.28	.58	.63	.39	.37	.31	.57	.65	.39	.24	.26	.74							
	VM	.46	.33	.28	.28	.22	.58	.32	.42	.25	.27	.59	.38	.36	.37	.37						
Year four	CR	.43	.41	.22	.33	.28	.46	.42	.43	.27	.28	.35	.47	.34	.41	.38	.37					
	CI	.19	.25	.35	.20	.22	.36	.14	.41	.20	.21	.34	.20	.38	.26	.33	.29	.45				
	WM	.30	.35	.38	.71	.71	.35	.22	.20	.63	.59	.35	.20	.22	.68	.65	.24	.30	.31			
	DM	.50	.47	.33	.64	.66	.51	.39	.32	.56	.50	.46	.32	.22	.70	.74	.44	.39	.33	.69		
	VM	.44	.29	.32	.30	.31	.55	.28	.41	.28	.18	.48	.41	.32	.34	.24	.61	.37	.29	.25	.35	

Significance value at .05 level = .174

Significance value at .01 level = .228

Table 29

PREDICTION EQUATIONS: FOURTH YEAR PIAGETIAN TASKS FROM YEAR 1 TO 4 VARIABLES, WITHOUT AND WITH AGE AS A PREDICTOR

	Standardized Regression Weights					Multiple R	F
Year 4CI		$.237CI_1$			$+ .243VM_1$	.412	$13.39_{(2,131)}$
From Year 1	$-.271 A$	$+ .274CI_1$			$+ .433VM_1$	.446	$10.78_{(3,130)}$
Year 4CR			$+ .179WM_1$		$+ .388VM_1$	.486	$20.22_{(2,131)}$
From Year 1	$.161 A$		$+ .157WM_1$		$+ .274VM_1$	.496	$14.15_{(3,130)}$
Year 4CI		$.330CI_2$			$+ .214VM_2$	.456	$17.20_{(2,131)}$
From Year 2	$-.101 A$	$+ .334CI_2$			$+ .260VM_2$	.463	$11.83_{(3,130)}$
Year 4CR		$.320CR_2$	$+ .328CI_2$			.523	$24.66_{(2,131)}$
From Year 2	$.224 A$	$+ .243CR_2$	$+ .262CI_2$			.557	$19.48_{(3,130)}$
Year 4CI			$.319CI_3$	$+ .246DM_3$		.451	$16.72_{(2,131)}$
From Year 3	$-.011 A$		$+ .320CI_3$	$+ .250DM_3$		.451	$11.07_{(3,130)}$
Year 4CR		$.374CR_3$	$+ .189CI_3$	$+ .243DM_3$		.578	$21.70_{(3,130)}$
From Year 3	$.184 A$	$+ .322CR_3$	$+ .162CI_3$	$+ .185DM_3$		.598	$17.97_{(4,129)}$
Year 4CI		$.389CR_4$		$+ .195WM_4$		.484	$20.05_{(2,131)}$
From Year 4	$-.098 A$	$+ .402CR_4$		$+ .226WM_4$		.486	$13.42_{(3,130)}$
Year 4CR			$.316CI_4$	$+ .211DM_4$	$+ .207VM_4$	.548	$18.62_{(3,130)}$
From Year 4	$.363 A$		$+ .379CI_4$			.572	$31.79_{(2,131)}$

A: Age

CR: Combinatorial Reasoning

CI: Class Inclusion

WM: Word Memory Span

DM: Digit Memory Span

VM: Visual Orientation Memory

$rACR_4 = .434$

$rACI_4 = .188$

Table 30

CROSS-LAGGED CORRELATIONS:

VISUAL MEMORY (VM) AND CLASS INCLUSION (CI)

Year	Observed		Corrected	
	VM	CI	VM	CI
1	.47		.43	1
	.65	.44	.41 .37	
2	.39		.43	2
		K_{VM} = .85		
		K_{CI} = .98		
			Z = .45	
2	.39		.37	2
	.59	.44	.38 .45	
3	.36		.39	3
		K_{VM} = 1.06		
		K_{CI} = .85		
3	.36		.35	3
	.61	.38	.41 .23	
4	.29		.31	4
		K_{VM} = .75		
		K_{CI} = 1.20		
			Z = 1.88	
1	.47		.39	1
	.55	.25	.34 .30	
4	.29		.35	4
		K_{VM} = .71		
		K_{CI} = .97		

Table 31

CROSS-LAGGED CORRELATIONS:

VISUAL MEMORY (VM) AND COMBINATORIAL REASONING (CR)

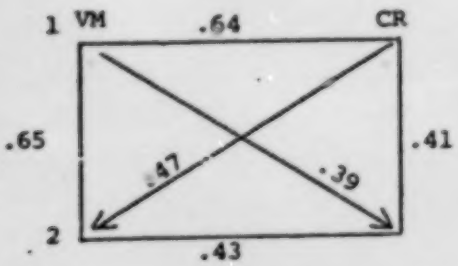
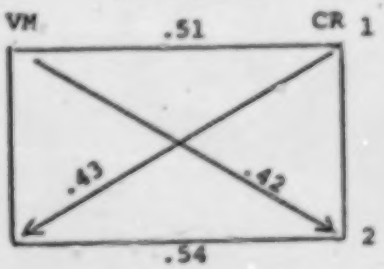
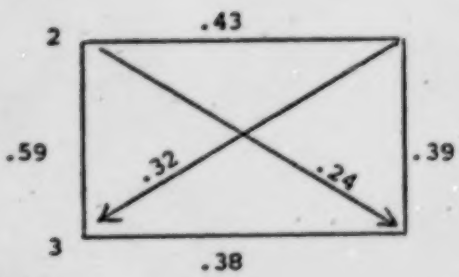
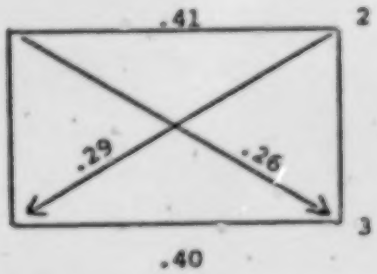
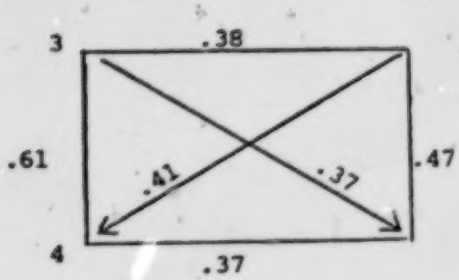
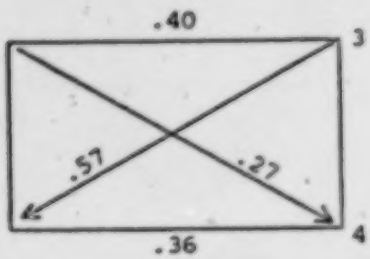
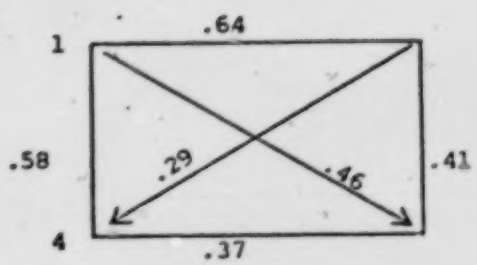
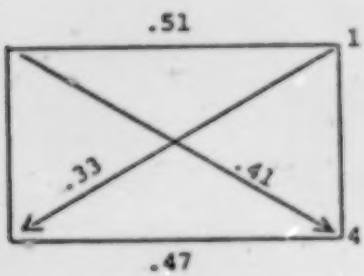
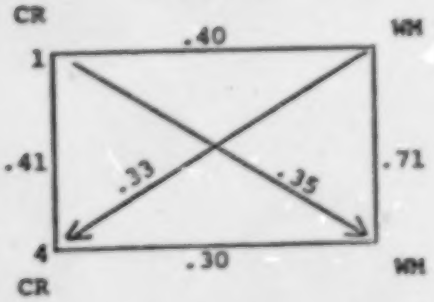
Year	Observed		Corrected
1		K_{VM} = .85 K_{CR} = .73	
2		K_{VM} = 1.06 K_{CR} = .89	
3		K_{VM} = .75 K_{CR} = 1.43	
			z = 3.38
1		K_{VM} = .71 K_{CR} = .89	
			z = .84

Table 32

CROSS-LAGGED CORRELATIONS:

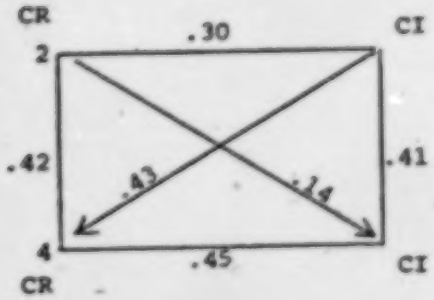
WORD MEMORY, DIGIT MEMORY, AND THE PIAGETIAN VARIABLES

Observed



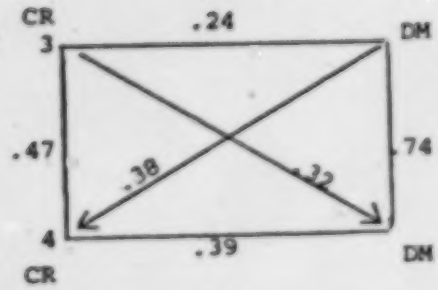
K_{CR} = .89

K_{WM} = .90



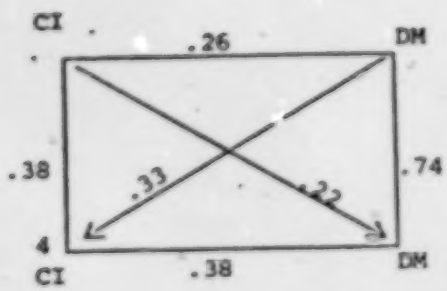
K_{CR} = 1.23

K_{CI} = 1.01



K_{CR} = 1.43

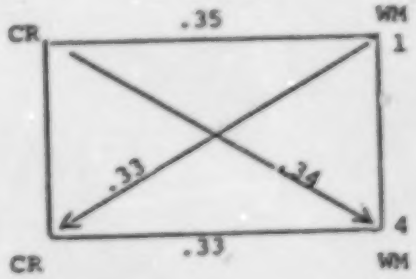
K_{DM} = 1.51

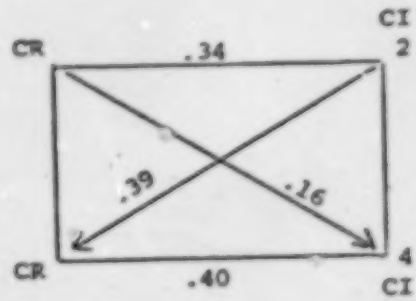


K_{CI} = 1.20

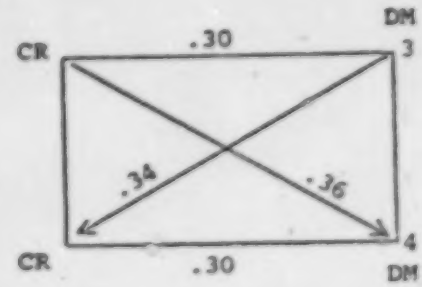
K_{DM} = 1.15

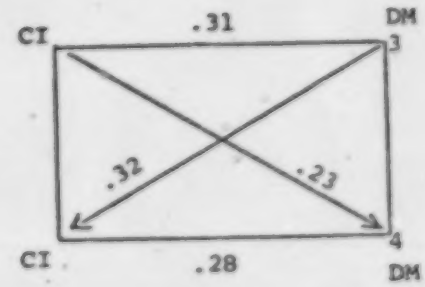
Corrected





z = 2.28





Partial Correlations Year 4

rCICR·VM = .38 rCICR·WM = .37

rCICR·VMDM = .33

Table 33

FOUR-WAVE CAUSAL EQUATIONS

X	Y	$rx_1y_2rx_2y_3rx_3y_4$ $- rx_2y_2rx_3y_3rx_1y_4$	$rx_2y_1rx_3y_2rx_4y_3$ $- rx_2y_2rx_3y_3rx_4y_1$	$\frac{rx_1y_2rx_2y_3rx_3y_4}{rx_1y_4}$ $- \frac{rx_2y_1rx_3y_2rx_4y_3}{rx_4y_1}$
CR	VM	.014	-.041	.137
CR	WM	-.008	-.020	.036
CR	DM	-.020	-.012	.001
CR	CI	-.001	.026	-.118
CI	VM	.006	-.006	.038
CI	WM	-.015	-.004	-.015
CI	DM	-.017	.001	-.052

Appendix

Means and Standard Deviations for the Tasks Administered to the Longitudinal and Testing Control Subjects

Table A1

Means and Standard Deviations for the Four Class *Groupement* Tasks Administered to the Longitudinal and Testing Control Subjects

Assessment condition and grade	*Groupements* I		II		III		IV		Total class	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Longitudinal sample										
Second										
Males (n = 25)	5.20	1.41	4.88	1.24	3.72	2.07	5.56	2.60	19.36	5.16
Females (n = 21)	5.29	1.55	4.57	1.36	4.10	2.21	5.38	2.25	19.33	4.80
Total (n = 46)	5.24	1.46	4.74	1.29	3.89	2.12	5.48	2.42	19.35	4.94
Fifth										
Males (n = 24)	6.00	1.74	6.00	1.64	4.75	2.23	7.13	1.19	23.87	5.71
Females (n = 26)	5.54	1.77	5.77	1.73	3.85	2.43	6.77	2.35	21.92	6.66
Total (n = 50)	5.76	1.76	5.88	1.67	4.28	2.36	6.94	1.88	22.86	6.24
Eighth										
Males (n = 24)	6.54	1.64	6.38	1.79	5.08	2.73	7.00	1.62	25.00	6.50
Females (n = 28)	6.75	1.48	6.71	1.51	6.11	2.28	7.32	1.36	26.89	5.70
Total (n = 52)	6.65	1.55	6.56	1.64	5.64	2.53	7.17	1.48	26.02	6.10
Combined grades										
Males (n = 73)	5.90	1.68	5.74	1.68	4.51	2.40	6.55	2.01	22.70	6.24
Females (n = 75)	5.92	1.71	5.79	1.76	4.76	2.51	6.59	2.13	23.05	6.56
Total (n = 148)	5.91	1.69	5.76	1.71	4.64	2.45	6.57	2.07	22.88	6.38
Testing control sample										
Second										
Males (n = 10)	4.70	1.77	5.30	1.70	3.50	2.07	4.00	2.05	17.50	3.89
Females (n = 10)	4.50	1.72	4.50	1.43	2.40	1.43	4.60	2.55	16.00	4.76
Total (n = 20)	4.60	1.70	4.90	1.59	2.95	1.82	4.30	2.27	16.75	4.30
Fifth										
Males (n = 12)	5.83	1.85	5.83	1.75	3.83	1.99	4.67	3.05	20.17	7.17
Females (n = 10)	5.60	1.78	5.40	1.90	4.40	2.46	7.00	2.54	22.40	6.11
Total (n = 22)	5.73	1.78	5.64	1.79	4.09	2.18	5.73	3.01	21.18	6.65
Eighth										
Males (n = 12)	7.75	.62	7.50	.90	6.50	1.57	7.58	.90	29.33	2.93
Females (n = 12)	6.50	1.45	6.08	1.56	5.42	2.50	6.08	2.19	24.08	6.77
Total (n = 24)	7.13	1.26	6.79	1.44	5.96	2.12	6.83	1.81	26.71	5.77
Combined grades										
Males (n = 34)	6.18	1.93	6.27	1.73	4.68	2.28	5.50	2.65	22.62	7.12
Females (n = 32)	5.59	1.79	5.38	1.72	4.16	2.49	5.91	2.53	21.03	6.79
Total (n = 66)	5.89	1.87	5.83	1.77	4.42	2.38	5.70	2.58	21.85	6.95

Table A2

Means and Standard Deviations for the Four Relations *Groupement* Tasks Administered to the Longitudinal and Testing Control Subjects

Assessment condition and grade	*Groupements*									
	V		VI		VII		VIII		Total class	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Longitudinal sample										
Second										
Males (n = 25)	7.44	1.08	7.44	1.26	7.44	1.19	7.16	.90	29.48	2.65
Females (n = 21)	7.24	1.48	7.29	1.27	6.67	1.56	5.71	1.93	26.90	4.31
Total (n = 46)	7.35	1.27	7.37	1.25	7.09	1.41	6.50	1.62	28.30	3.70
Fifth										
Males (n = 24)	7.79	.59	7.83	.82	7.42	1.32	7.71	.55	30.75	1.96
Females (n = 26)	7.50	1.03	7.50	1.58	7.54	1.27	7.42	.99	29.96	2.58
Total (n = 50)	7.64	.85	7.66	1.27	7.48	1.28	7.56	.81	30.34	2.32
Eighth										
Males (n = 24)	7.83	.48	7.75	.74	7.50	1.06	7.54	1.10	30.62	2.55
Females (n = 28)	7.79	.57	7.71	1.18	7.68	.98	7.50	1.14	30.68	3.17
Total (n = 52)	7.81	.53	7.73	.99	7.60	1.01	7.52	1.11	30.65	2.88
Combined grades										
Males (n = 73)	7.69	.78	7.67	.97	7.45	1.18	7.47	.90	30.27	2.45
Females (n = 75)	7.53	1.06	7.52	1.35	7.35	1.32	6.97	1.56	29.37	3.67
Total (n = 148)	7.61	.93	7.60	1.18	7.40	1.25	7.22	1.30	29.82	3.15
Testing control sample										
Second										
Males (n = 10)	6.40	1.78	7.40	1.08	7.40	1.35	5.80	1.75	27.00	3.86
Females (n = 10)	7.30	1.16	7.50	.71	5.60	1.95	5.40	1.35	25.80	2.94
Total (n = 20)	6.85	1.53	7.45	.89	6.50	1.88	5.60	1.54	26.40	3.39
Fifth										
Males (n = 12)	7.67	.78	8.00	.00	7.08	1.24	6.92	1.31	29.67	2.53
Females (n = 10)	7.50	1.27	7.90	.32	6.30	2.21	6.80	1.55	28.50	4.72
Total (n = 22)	7.59	1.01	7.96	.21	6.73	1.75	6.86	1.39	29.14	3.64
Eighth										
Males (n = 12)	7.92	.29	7.92	.29	7.08	2.23	7.42	1.73	30.33	3.77
Females (n = 12)	7.67	.78	7.50	1.73	8.00	.00	7.08	1.62	30.25	3.11
Total (n = 24)	7.79	.59	7.71	1.23	7.54	1.61	7.25	1.65	30.29	3.38
Combined grades										
Males (n = 34)	7.38	1.23	7.79	.64	7.18	1.64	6.77	1.69	29.12	3.60
Females (n = 32)	7.50	1.05	7.63	1.13	6.72	1.90	6.47	1.65	28.31	3.99
Total (n = 66)	7.44	1.14	7.71	.91	6.96	1.78	6.62	1.66	28.73	3.78

Table A3

Means and Standard Deviations for Class Inclusion, Combinatorial Reasoning, Auditory Memory Span Test, Auditory Sequential Memory Test, and Visual Orientation Memory for the Longitudinal and Testing Control Subjects

Assessment condition and grade	CI		CR		AMS		ASM		VOM	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Longitudinal sample										
Second										
Males (n = 25)	4.04	1.02	21.00	7.54	31.40	8.63	29.44	10.45	15.[illegible]	2.88
Females (n = 21)	3.86	1.20	17.86	9.48	32.62	9.35	32.43	15.53	13.67	3.15
Total (n = 46)	3.96	1.09	19.57	8.53	31.96	8.89	30.80	12.95	14.78	3.15
Fifth										
Males (n = 24)	4.67	.76	25.87	3.71	38.79	10.95	35.87	13.99	18.00	1.64
Females (n = 26)	4.08	1.20	23.15	6.35	32.92	9.96	29.88	13.11	16.31	3.95
Total (n = 50)	4.36	1.04	24.46	5.38	35.74	10.76	32.76	13.73	17.12	3.15
Eighth										
Males (n = 24)	4.33	.92	25.29	6.40	45.92	9.66	46.92	15.40	17.79	1.72
Females (n = 28)	4.93	.26	26.57	2.71	46.00	8.79	45.21	10.58	18.54	1.79
Total (n = 52)	4.65	.71	25.98	4.77	45.96	9.11	46.00	12.92	18.19	1.78
Combined grades										
Males (n = 73)	4.34	.93	24.01	6.42	38.60	11.35	37.30	15.09	17.15	2.38
Females (n = 75)	4.33	1.06	22.95	7.28	37.72	11.26	36.32	14.59	16.40	3.60
Total (n = 148)	4.34	.99	23.47	6.87	38.16	11.27	36.80	14.80	16.77	3.07
Testing control sample										
Second										
Males (n = 10)	2.70	1.49	17.00	10.01	30.00	4.42	26.10	6.37	15.60	2.41
Females (n = 10)	3.00	1.25	12.70	10.09	32.10	9.96	30.90	16.13	12.90	2.51
Total (n = 20)	2.85	1.35	14.85	10.03	31.05	7.58	28.50	12.19	14.25	2.77
Fifth										
Males (n = 12)	3.58	1.00	24.33	6.80	42.17	9.68	38.67	14.25	15.50	4.27
Females (n = 10)	4.40	1.08	26.30	2.75	35.00	5.98	34.30	7.97	14.70	5.25
Total (n = 20)	3.96	1.09	25.23	5.34	38.91	8.82	36.68	11.77	15.14	4.64
Eighth										
Males (n = 12)	4.67	.49	27.83	.39	46.33	10.96	49.17	10.35	19.25	.97
Females (n = 12)	4.08	1.08	27.17	1.03	48.92	10.79	47.00	11.90	18.33	1.50
Total (n = 24)	4.38	.88	27.50	.83	47.62	10.72	48.08	10.96	18.79	1.32
Combined grades										
Males (n = 34)	3.71	1.29	23.41	7.92	40.06	11.10	38.68	14.23	16.85	3.35
Females (n = 32)	3.84	1.25	22.37	8.73	39.31	11.79	38.00	14.01	15.50	4.02
Total (n = 66)	3.77	1.26	22.91	8.27	39.70	11.36	38.35	14.02	16.20	3.72

Table A4

Means and Standard Deviations for the Some-All, Dichotomous Sorting, Cardinality, and Arithmetic Addition Tasks for the Longitudinal and Testing Control Subjects

Assessment condition and grade	Some-All		Dichotomous sorting		Cardinality		Arithmetic addition	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Longitudinal sample								
Second								
Males (n = 25)	3.84	.37	2.44	.87	3.84	1.11	15.24	2.03
Females (n = 21)	3.95	.22	2.10	.89	3.91	.94	15.14	1.96
Total (n = 46)	3.89	.31	2.28	.89	3.87	1.02	15.20	1.97
Fifth								
Males (n = 24)	3.96	.20	2.92	.28	4.42	.78	15.79	.66
Females (n = 26)	4.00	.00	2.77	.51	4.12	.82	16.00	.00
Total (n = 50)	3.98	.14	2.84	.42	4.26	.80	15.90	.46
Combined grades								
Males (n = 49)	3.90	.31	2.67	.69	4.12	.99	15.51	1.53
Females (n = 47)	3.98	.15	2.47	.78	4.02	.87	15.62	1.36
Total (n = 96)	3.94	.24	2.57	.74	4.07	.93	15.56	1.44
Testing control sample								
Second								
Males (n = 10)	3.70	.67	1.70	.82	3.00	1.25	13.90	5.00
Females (n = 10)	4.00	.00	1.90	.99	3.20	1.40	15.10	1.66
Total (n = 20)	3.85	.49	1.80	.89	3.10	1.29	14.50	3.68
Fifth								
Males (n = 12)	3.83	.39	2.50	.67	3.92	1.44	16.00	.00
Females (n = 10)	3.80	.63	3.00	.00	4.10	.74	15.90	.32
Total (n = 22)	3.82	.50	2.73	.55	4.00	1.15	15.95	.21
Combined grades								
Males (n = 22)	3.77	.53	2.14	.83	3.50	1.41	15.05	3.44
Females (n = 20)	3.90	.45	2.45	.89	3.65	1.18	15.50	1.24
Total (n = 42)	3.83	.49	2.29	.86	3.57	1.29	15.26	2.61

Table A5

Means and Standard Deviations for the Seriation, Length Transitivity, and Weight Transitivity Tasks Administered to the Longitudinal and Testing Control Subjects

Assessment condition and grade	Seriation		Length transitivity		Weight transitivity	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Longitudinal sample						
Second						
Males (n = 25)	3.60	1.04	4.12	1.88	4.80	1.00
Females (n = 21)	3.67	1.02	4.05	2.01	4.33	1.68
Total (n = 46)	3.63	1.02	4.09	1.92	4.59	1.36
Fifth						
Males (n = 24)	4.21	.78	4.79	1.02	5.00	.00
Females (n = 26)	4.19	.80	4.58	1.14	4.62	1.36
Total (n = 50)	4.20	.78	4.68	1.08	4.80	.99
Combined grades						
Males (n = 49)	3.90	.96	4.45	1.54	4.90	.71
Females (n = 47)	3.96	.93	4.34	1.59	4.49	1.50
Total (n = 96)	3.93	.94	4.40	1.56	4.70	1.18
Testing control sample						
Second						
Males (n = 10)	3.00	1.05	4.80	.63	4.50	1.58
Females (n = 10)	3.20	.63	3.00	2.58	3.60	2.27
Total (n = 20)	3.10	.85	3.90	2.05	4.05	1.96
Fifth						
Males (n = 12)	3.83	.72	4.17	1.95	5.00	.00
Females (n = 10)	4.10	.74	4.50	1.58	5.00	.00
Total (n = 22)	3.96	.72	4.32	1.76	5.00	.00
Combined grades						
Males (n = 22)	3.46	.96	4.46	1.50	4.77	1.07
Females (n = 20)	3.65	.81	3.75	2.22	4.30	1.72
Total (n = 42)	3.55	.89	4.12	1.89	4.55	1.42

Table A6

Means and Standard Deviations for the Number Conservation, Length Conservation, and Weight Conservation Tasks Administered to the Longitudinal and Testing Control Subjects

Assessment condition and grade	Number conservation		Length conservation				Weight conservation			
			Identity		Equivalence		Identity		Equivalence	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Longitudinal sample										
Second										
Males (n = 25)	6.88	.60	5.32	1.44	5.28	1.74	5.16	1.57	5.00	1.98
Females (n = 21)	6.24	1.97	4.71	1.62	4.86	1.77	4.10	2.07	3.62	2.65
Total (n = 46)	6.59	1.42	5.04	1.53	5.09	1.75	4.67	1.87	4.37	2.39
Fifth										
Males (n = 24)	7.00	0.00	5.67	1.13	5.67	1.13	5.83	.82	5.71	1.08
Females (n = 26)	7.00	0.00	5.92	.39	5.58	1.06	5.19	1.55	5.08	1.98
Total (n = 50)	7.00	0.00	5.80	.83	5.62	1.09	5.50	1.28	5.38	1.63
Combined grades										
Males (n = 49)	6.94	.43	5.49	1.29	5.47	1.47	5.49	1.29	5.35	1.63
Females (n = 47)	6.66	1.36	5.38	1.26	5.26	1.45	4.70	1.86	4.43	2.39
Total (n = 96)	6.80	1.00	5.44	1.27	5.37	1.46	5.10	1.64	4.90	2.08
Testing control sample										
Second										
Males (n = 10)	5.80	2.53	4.40	1.78	3.90	2.51	4.20	1.81	4.80	1.69
Females (n = 10)	6.60	.97	4.40	1.90	3.50	2.72	4.10	2.13	4.20	2.53
Total (n = 20)	6.20	1.91	4.40	1.79	3.70	2.56	4.15	1.93	4.50	2.12
Fifth										
Males (n = 12)	6.25	1.60	5.83	.39	4.83	2.04	5.08	1.56	3.92	2.71
Females (n = 10)	7.00	0.00	4.70	1.77	4.80	2.15	5.00	1.70	4.40	2.63
Total (n = 22)	6.59	1.22	5.32	1.32	4.82	2.04	5.05	1.59	4.14	2.62
Combined grades										
Males (n = 22)	6.05	2.03	5.18	1.40	4.41	2.26	4.68	1.70	4.32	2.30
Females (n = 20)	6.80	.70	4.55	1.79	4.15	2.48	4.55	1.93	4.30	2.52
Total (n = 42)	6.41	1.58	4.88	1.61	4.29	2.34	4.62	1.79	4.31	2.37

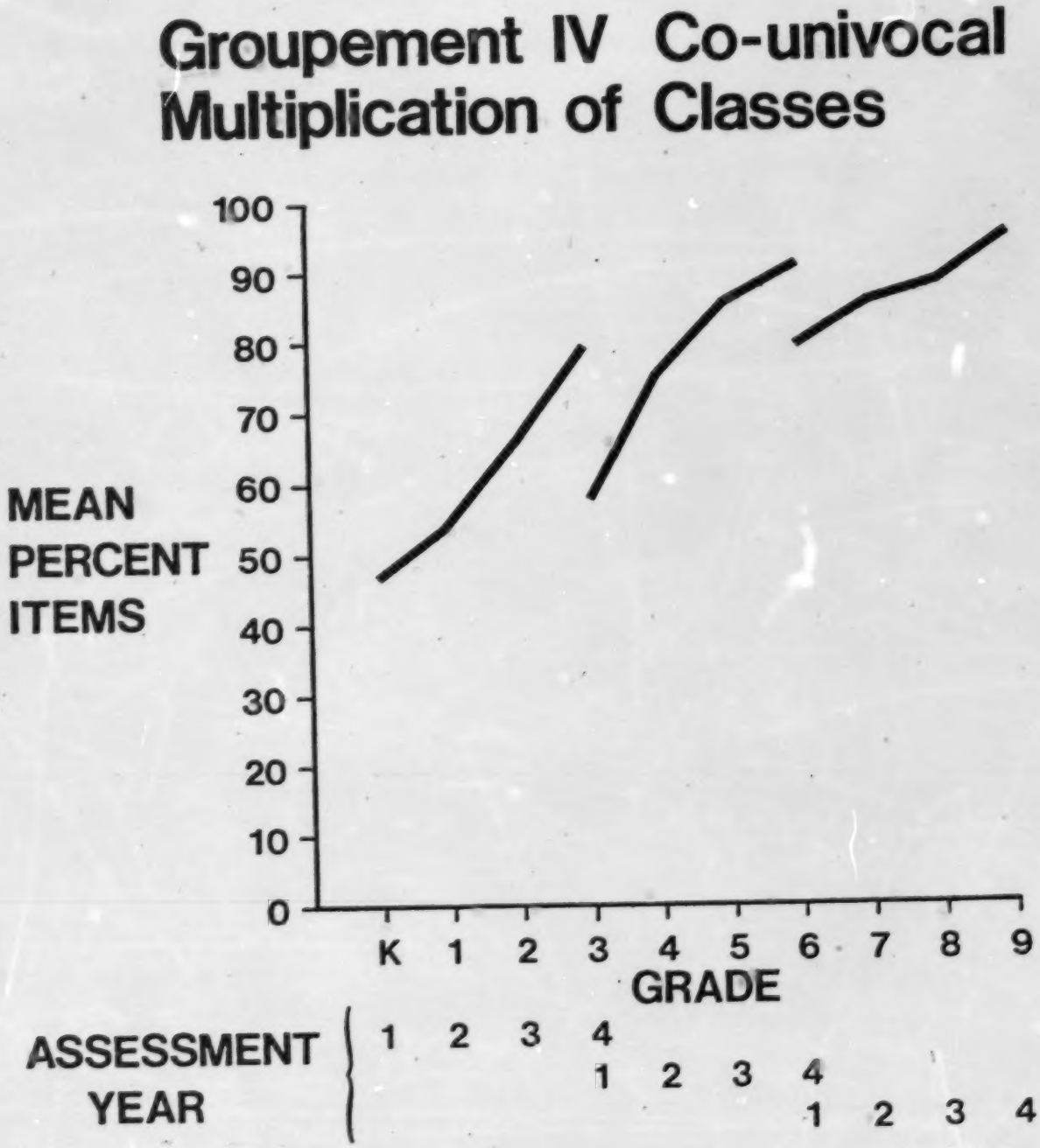


Figure 1. Mean percent items correct on groupment IV for subjects assessed in all four years.

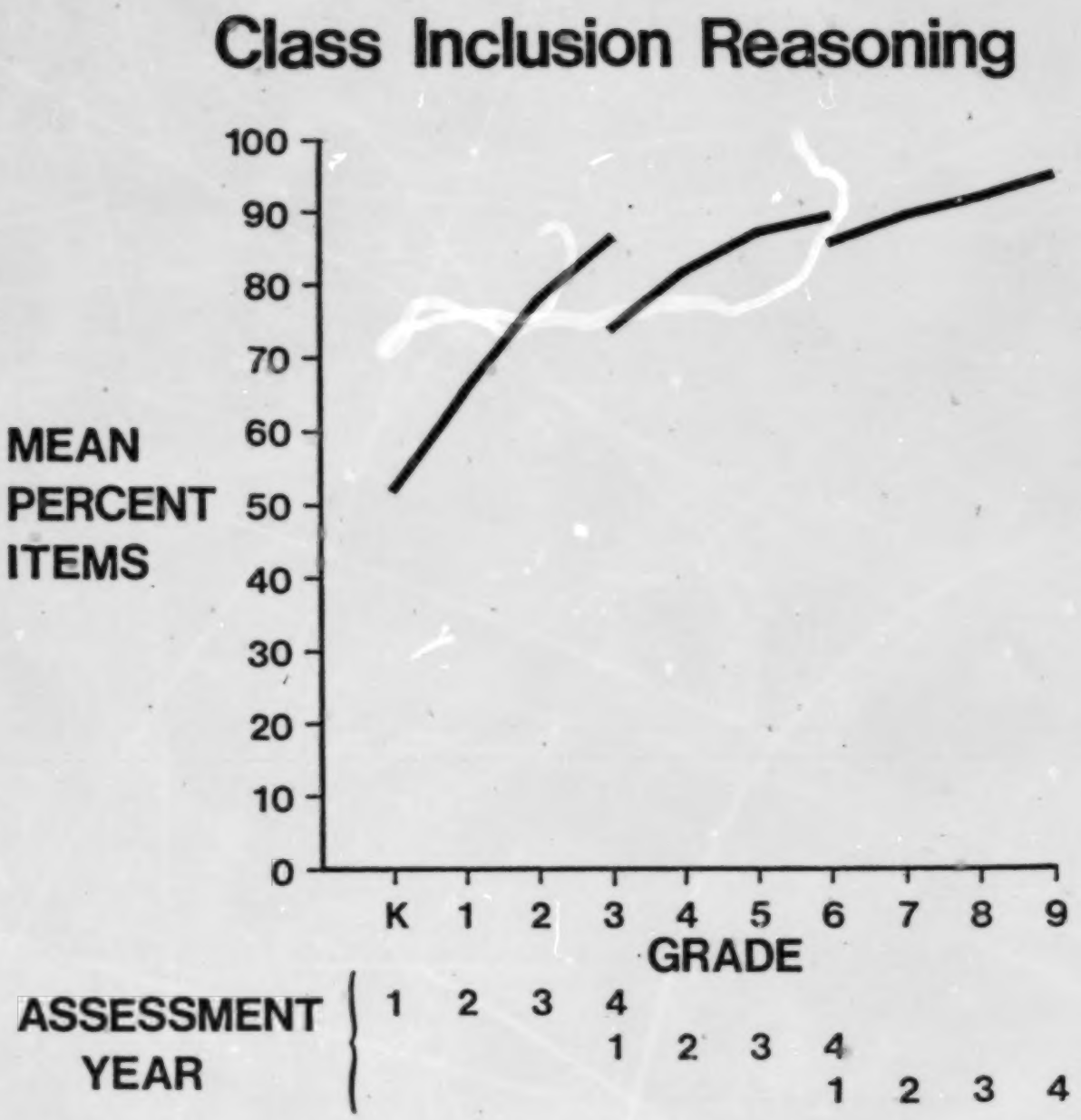


Figure 2. Mean percent items correct on class inclusion for subjects assessed in all four years.

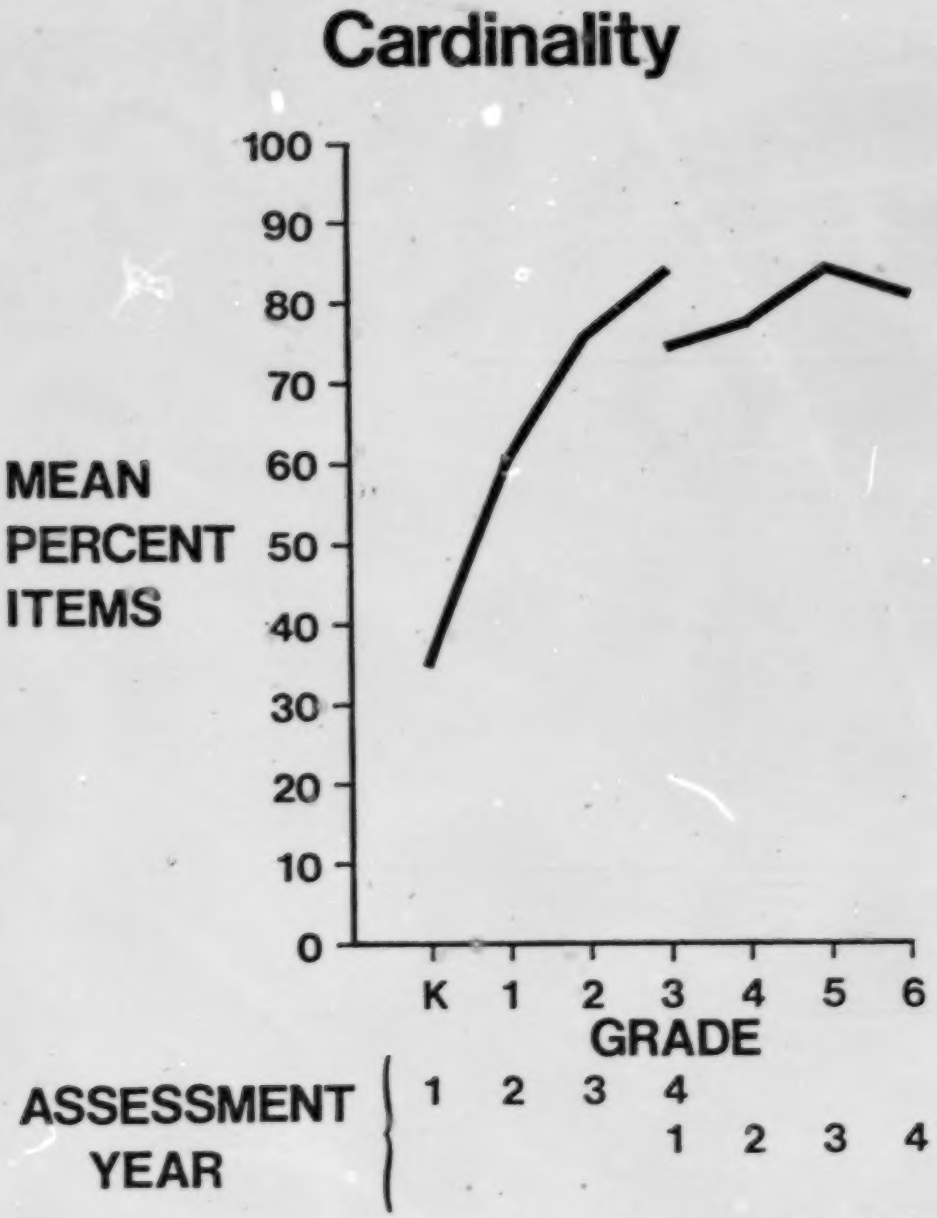


Figure 3. Mean percent items correct on cardinality for subjects assessed in all four years.

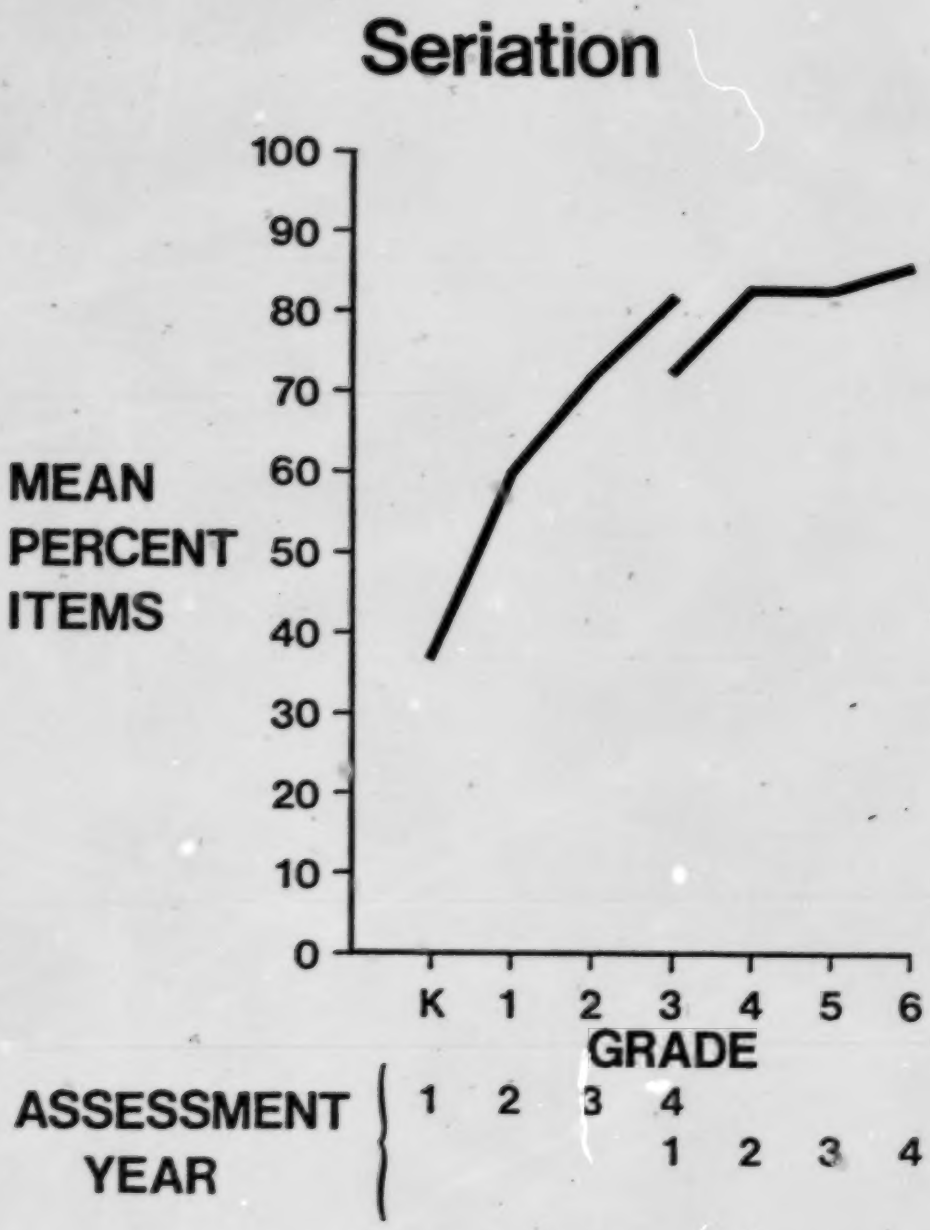


Figure 4. Mean percent items correct on seriation for subjects assessed in all four years.

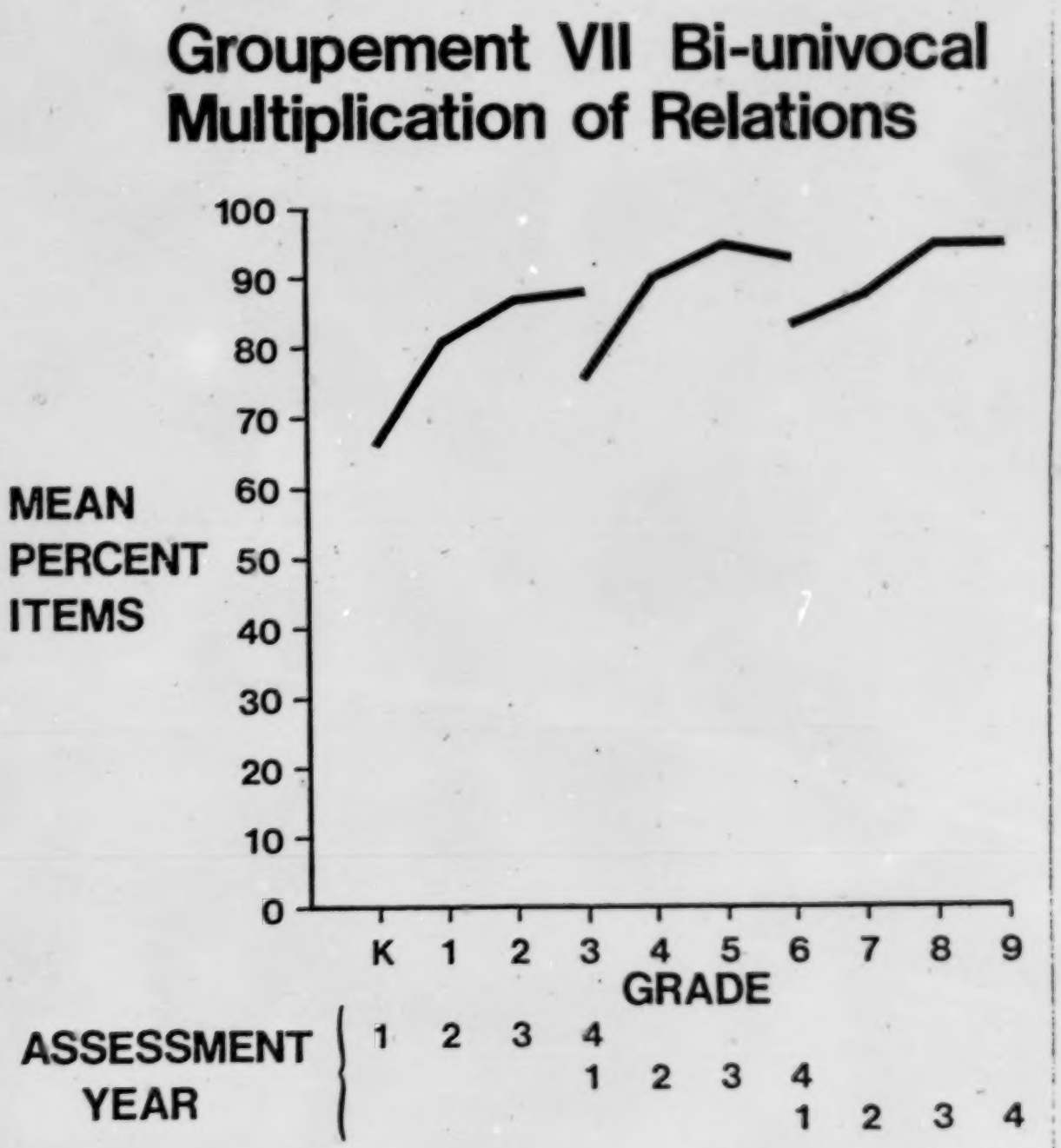


Figure 5. Mean percent items correct on groupment VII for subjects assessed in all four years.

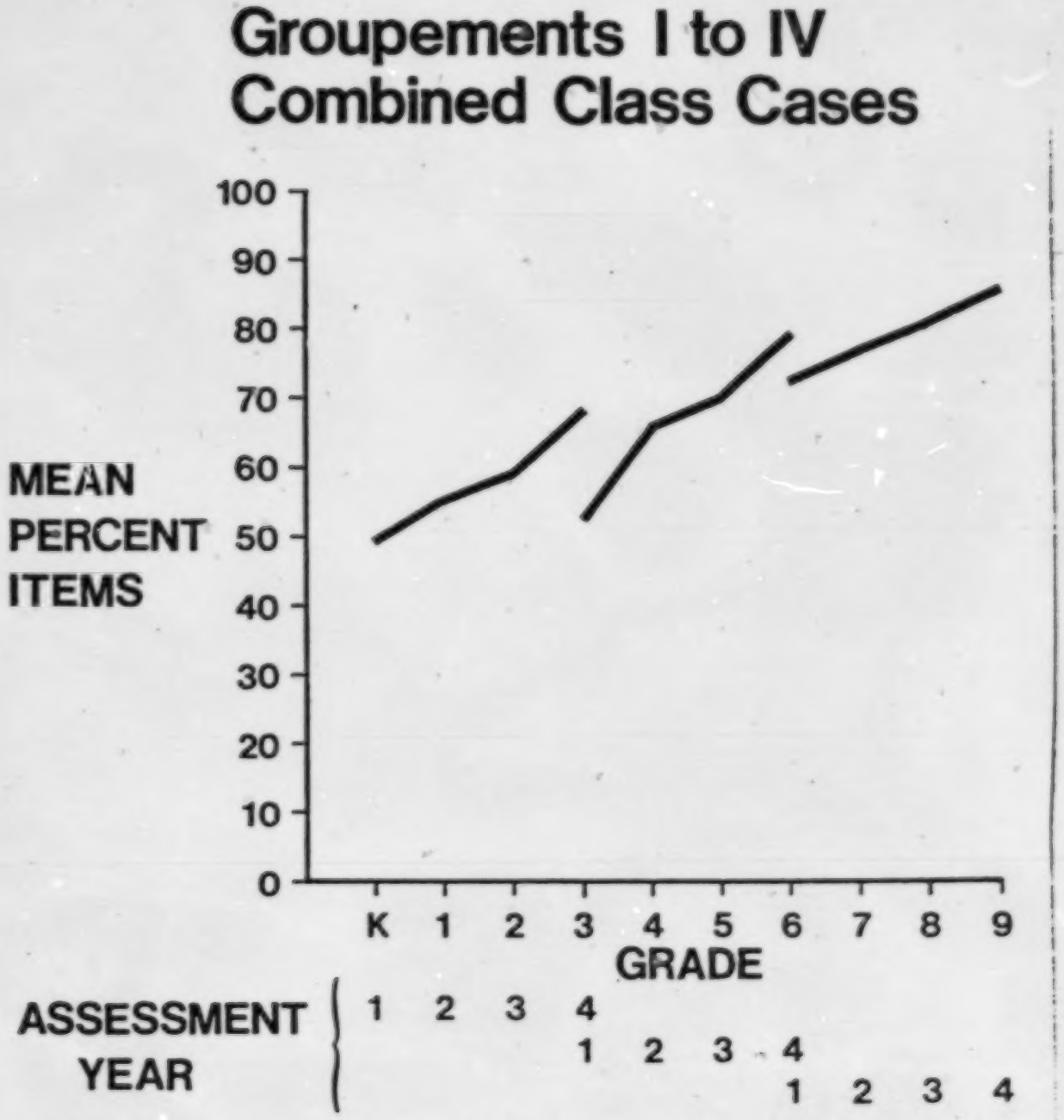


Figure 6. Mean percent items correct on groupments I-IV combined for subjects assessed in all four years.

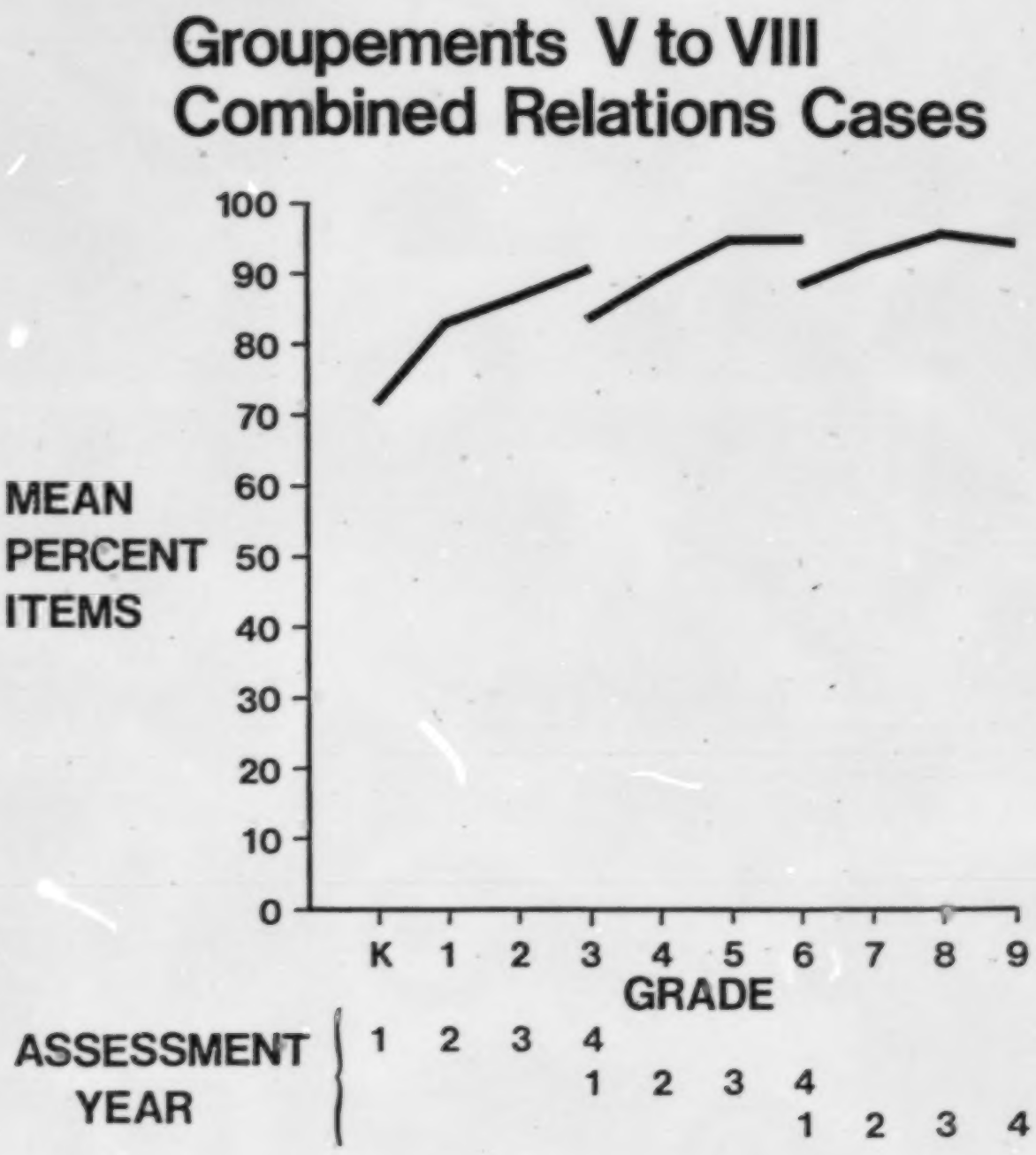


Figure 7. Mean percent items correct on groupments V-VIII combined for subjects assessed in all four years.

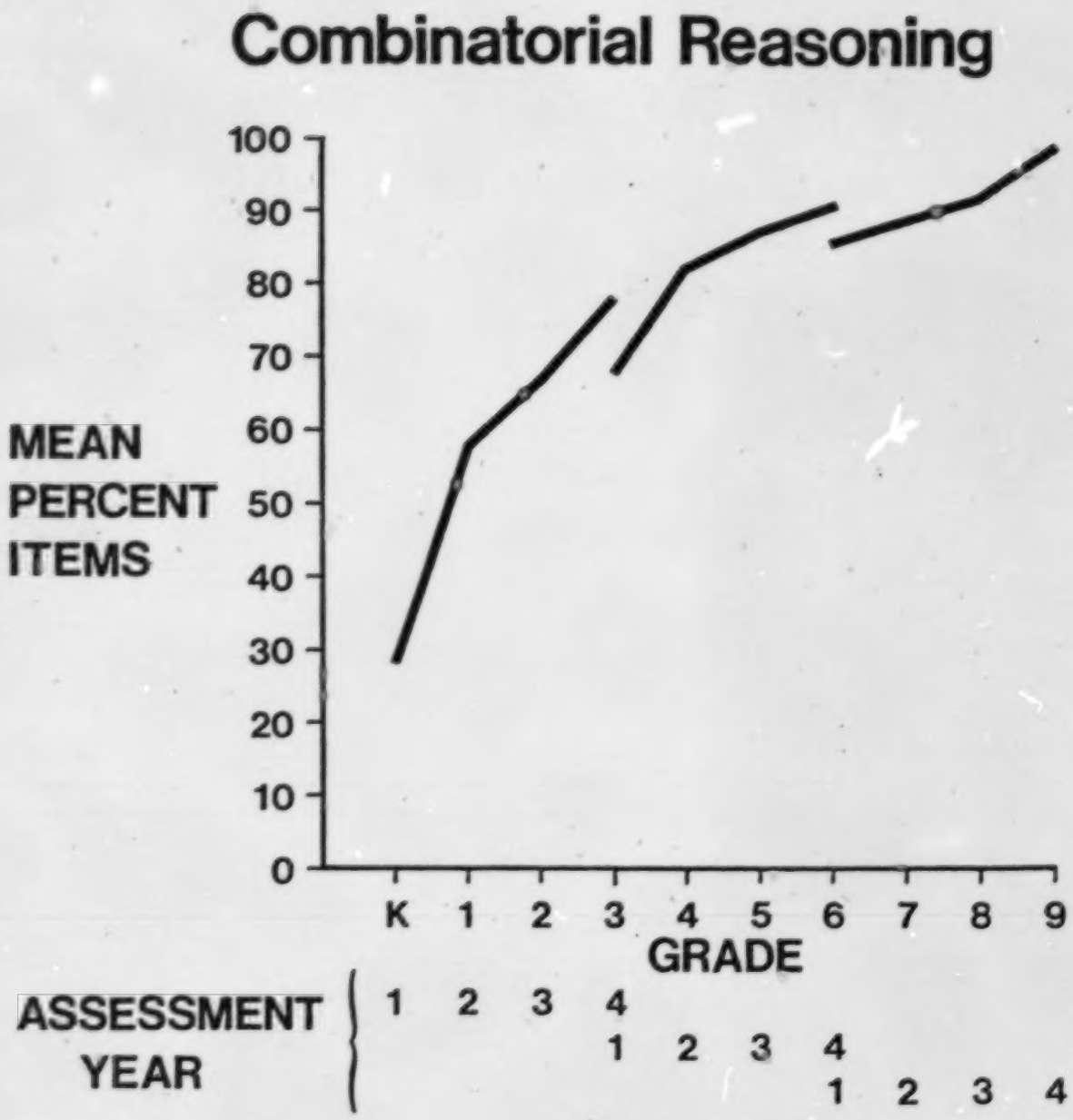


Figure 8. Mean percent items correct on combinatorial reasoning for subjects assessed in all four years.

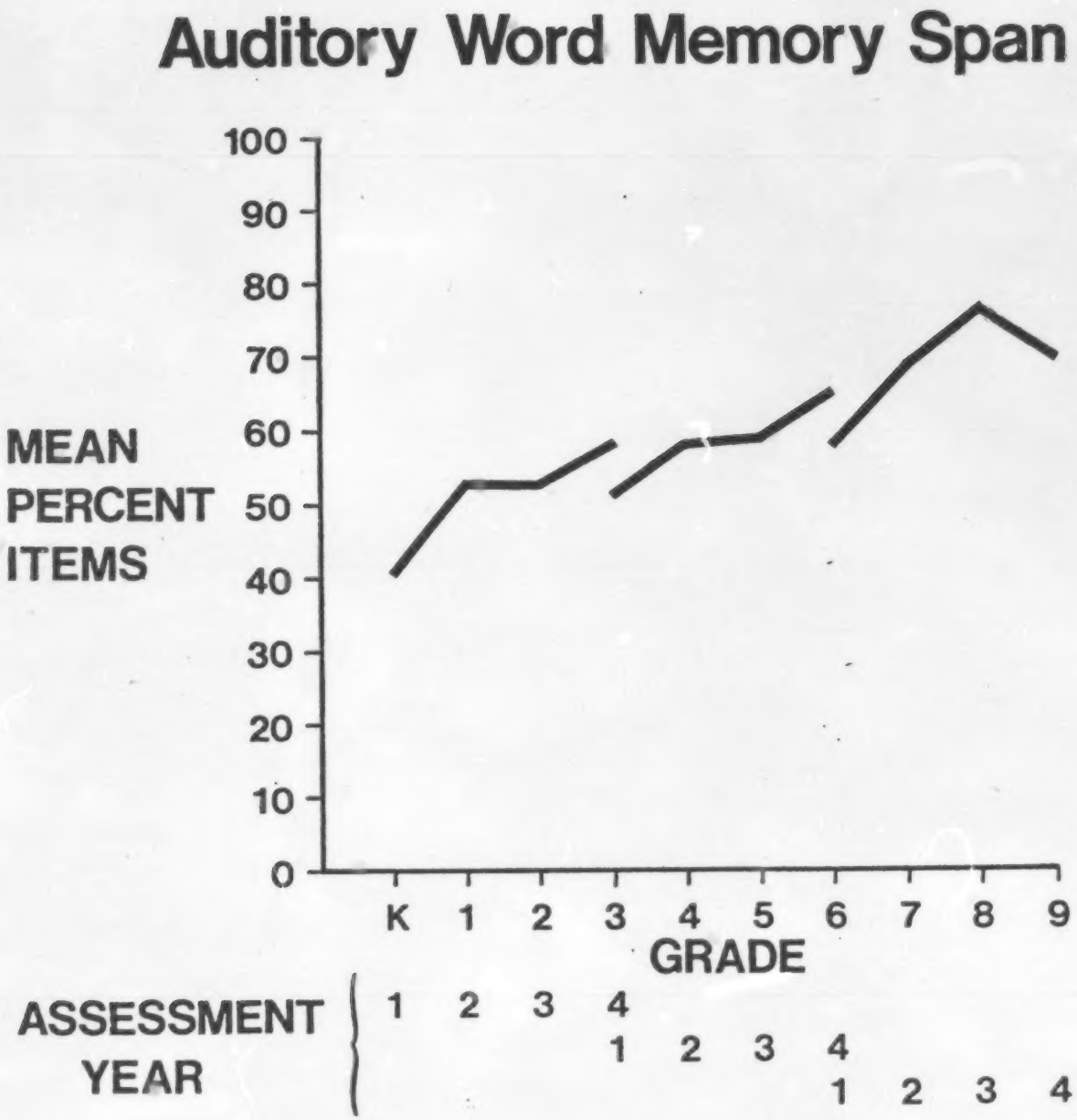


Figure 9. Mean percent items correct on auditory memory (word) span for subjects assessed in all four years.

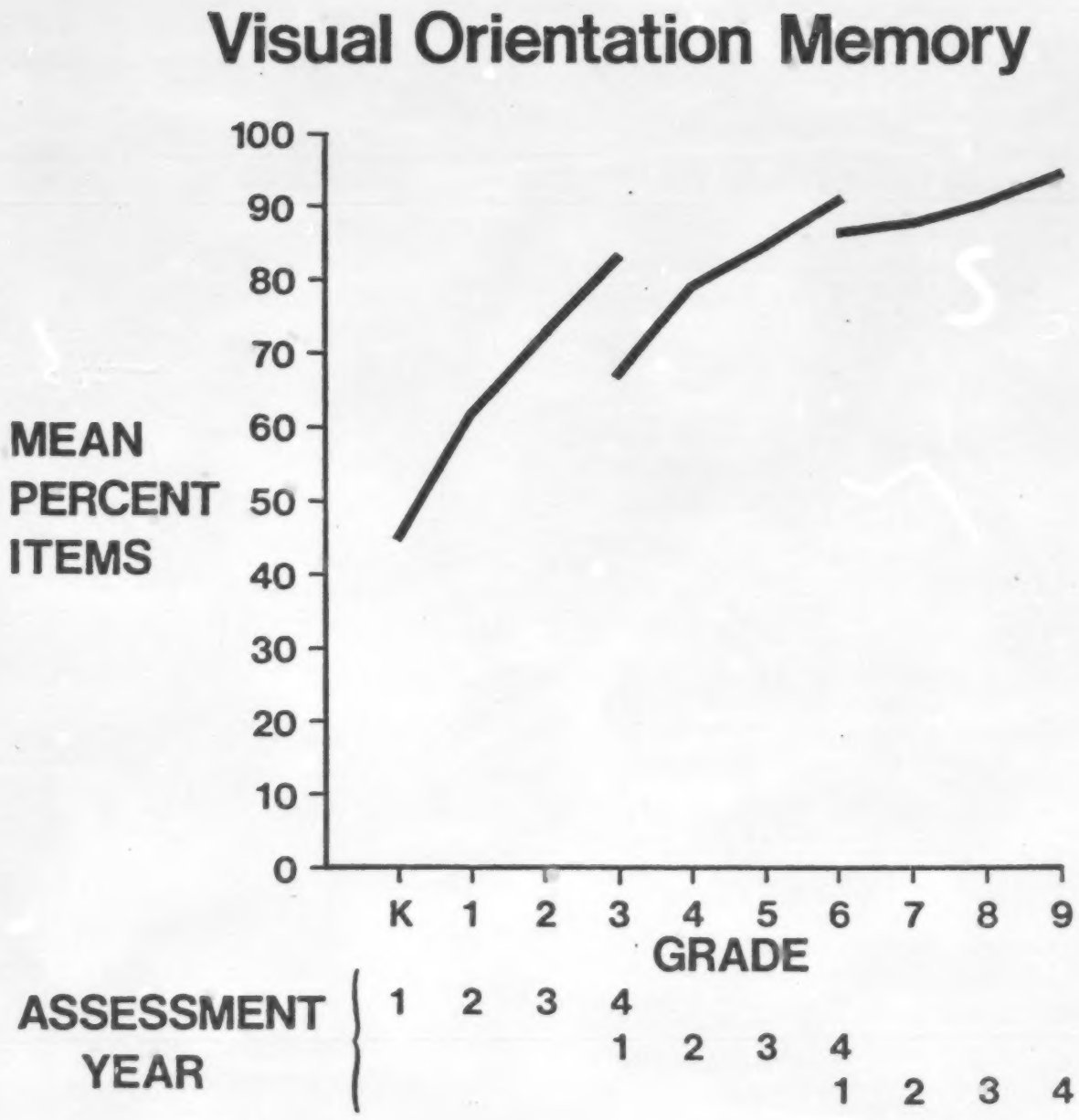


Figure 10. Mean percent items correct on visual orientation memory for subjects assessed in all four years.

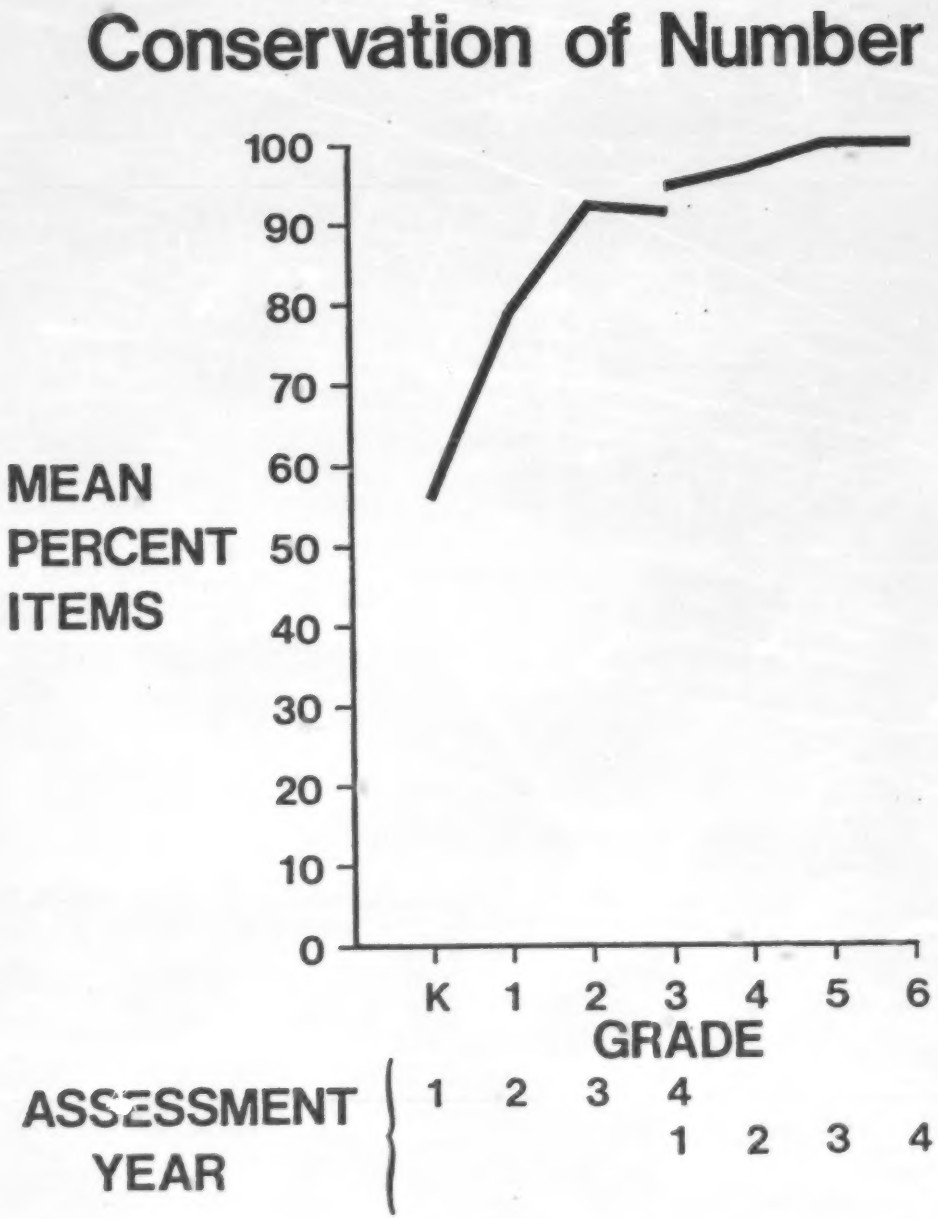


Figure 11. Mean percent items correct on conservation of number for subjects assessed in all four years.

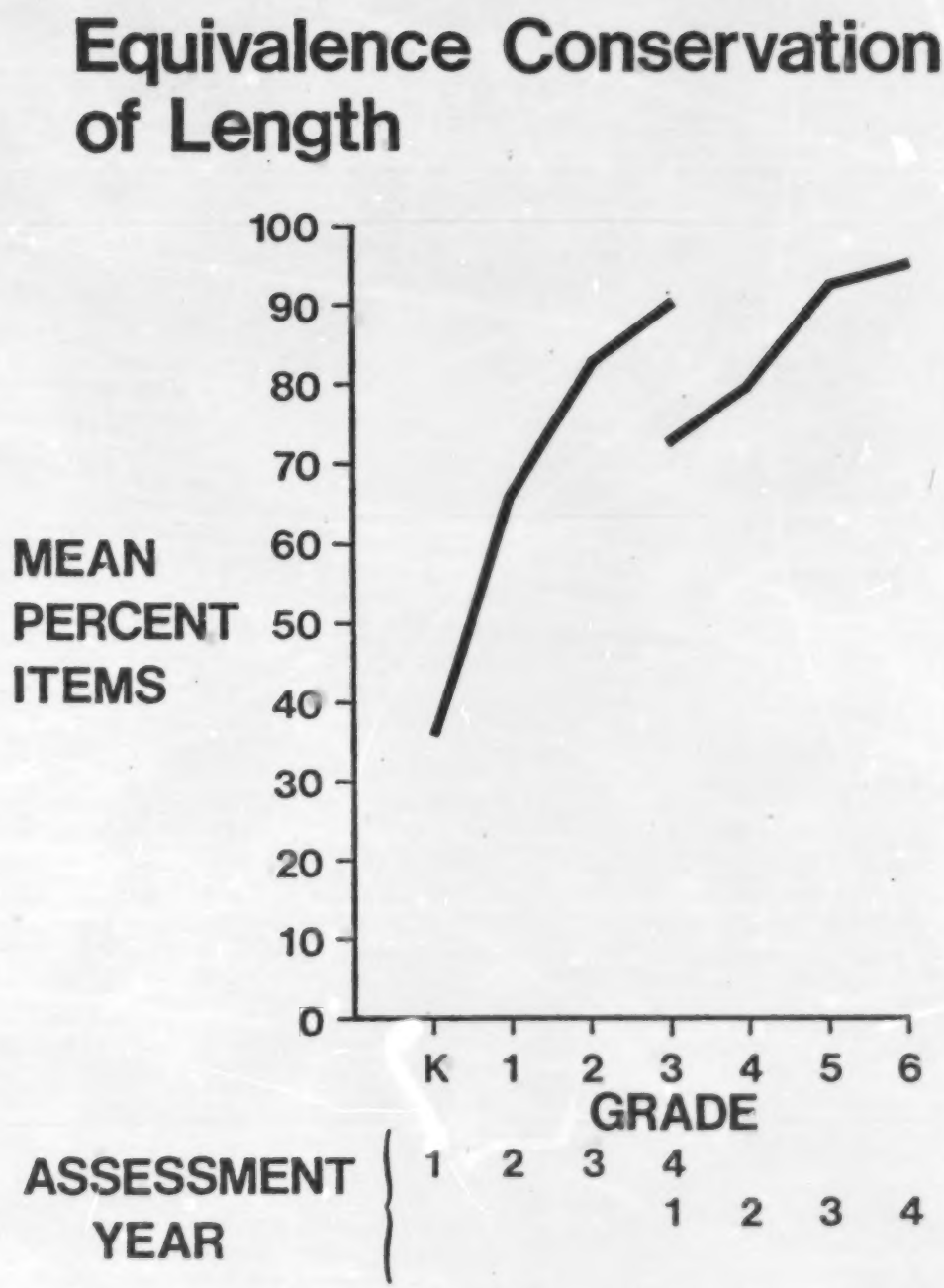


Figure 12. Mean percent items correct on equivalence conservation of length for subjects assessed in all four years.

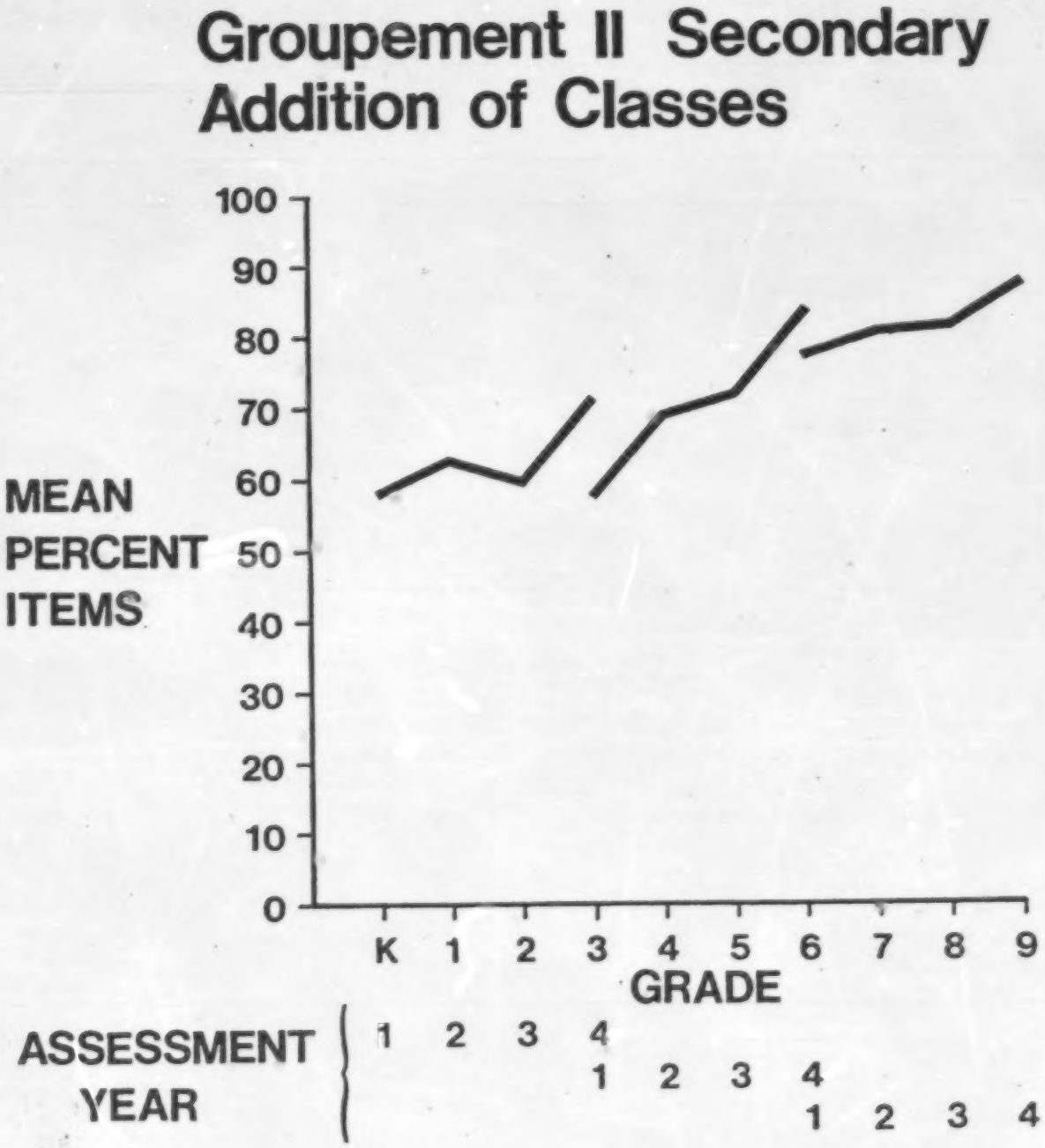


Figure 13. Mean percent items correct on groupment II for subjects assessed in all four years.

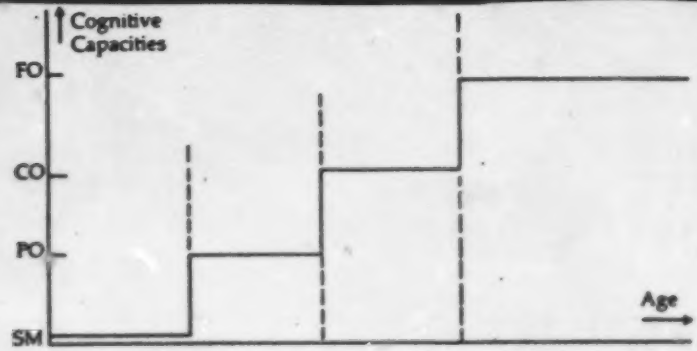


Figure 14A. Simple step function model of stage transition.

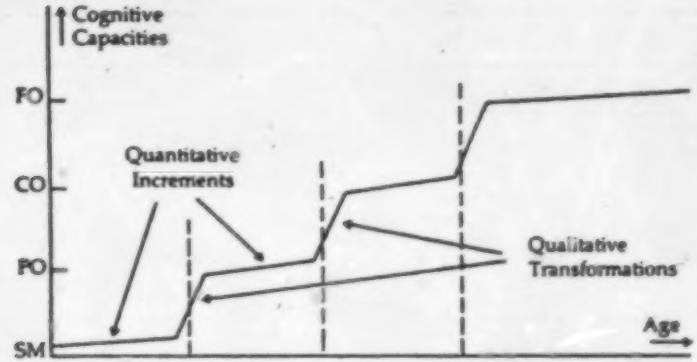


Figure 14B. Modified step function (after Flavell, 1971).

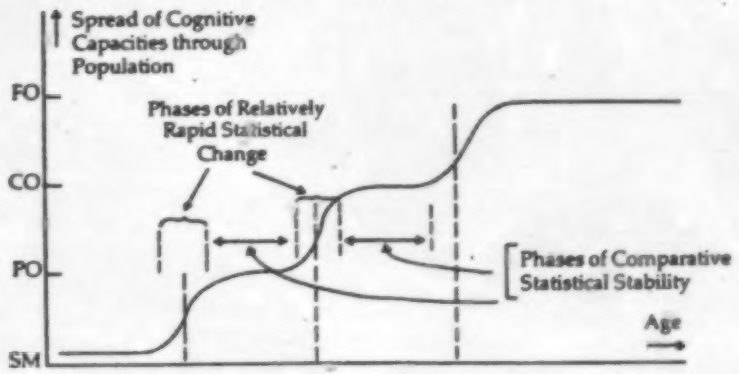


Figure 14C. Sigmoid sequence of stage transitions.

Feldman, C. F., & Toulmin, S. Logic and the Theory of Mind. In W. J. Arnold (Ed.), Nebraska symposium on motivation 1975: Conceptual foundations of psychology. Lincoln: University of Nebraska Press, 1975. P. 450.

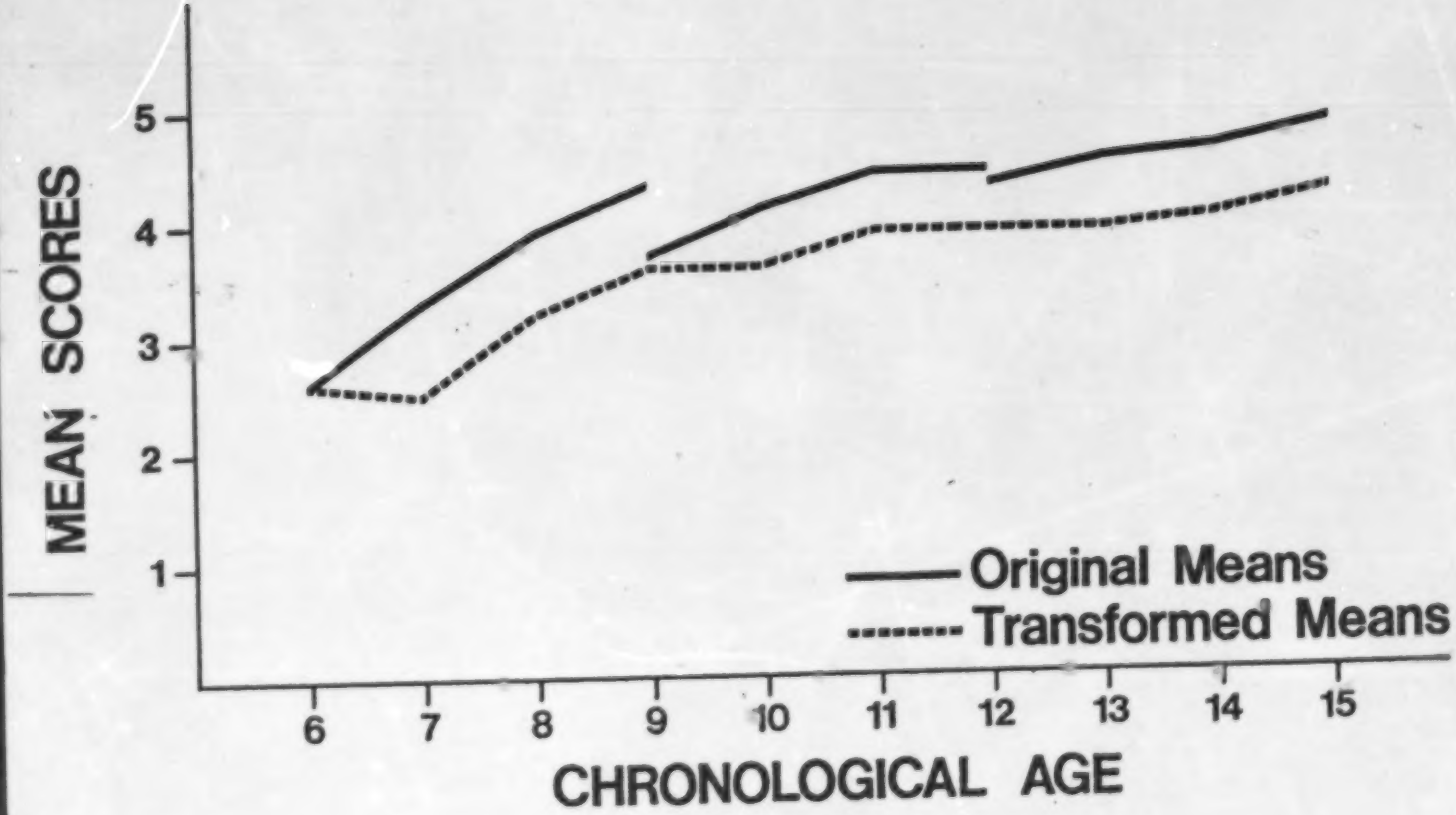


Figure 15. Class Inclusion Task Mean Scores Adjusted for Retest Effects